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MODERN NAVIGATION

FRANK SEYMOUR HASTINGS

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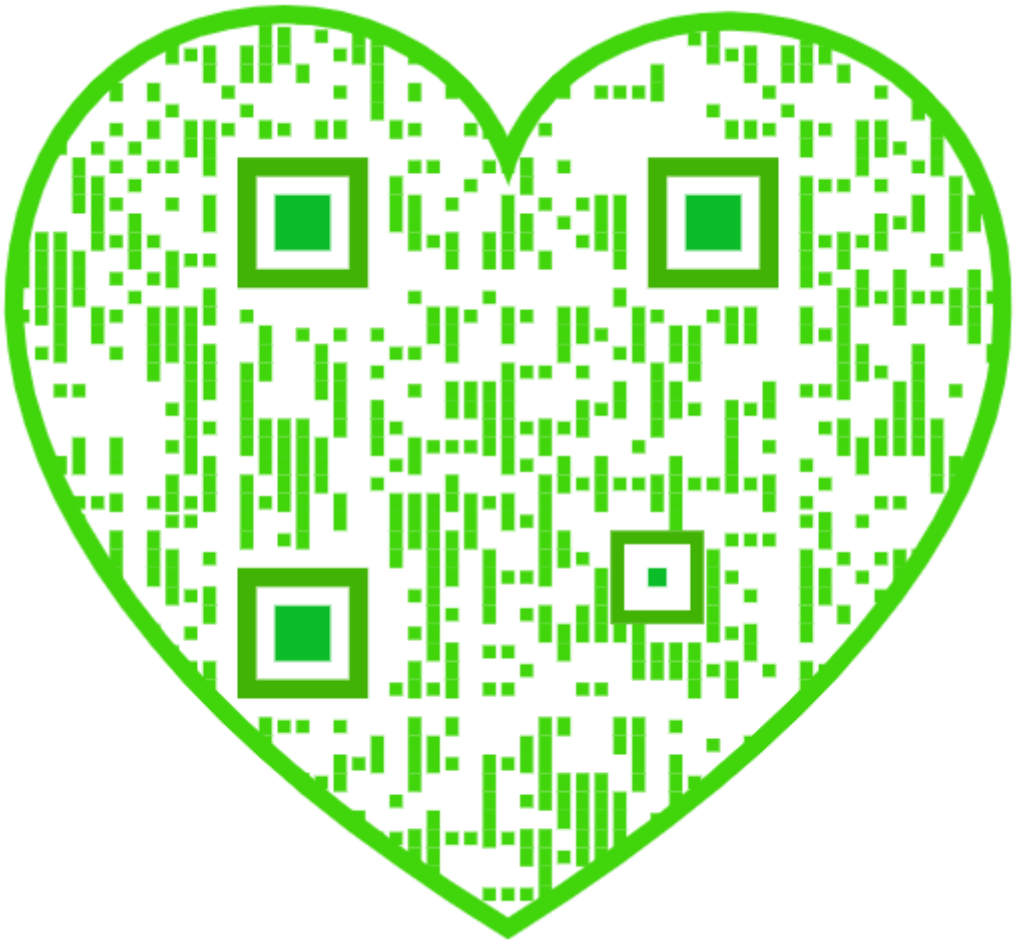

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MODERN NAVIGATION

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MODERN NAVIGATION

BY

SUMNER-ST. HILAIRE METHODS

THE FIRST PUBLISHED WORK DEVOTED EXCLUSIVELY TO THE ELUCIDATION OF THIS SUBJECT, NOW SO GENERALLY USED IN THE U. S. NAVY

BY

FRANK SEYMOUR HASTINGS

INSTRUCTOR IN NAVIGATION U. S. S. "GRANITE STATE"
(N. Y. NAVAL MILITIA)
EX-COMMODORE SEAWANHAKA CORINTHIAN YACHT CLUB
AUTHOR OF "NAVIGATION—A SHORT COURSE"

D. APPLETON AND COMPANY
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1918

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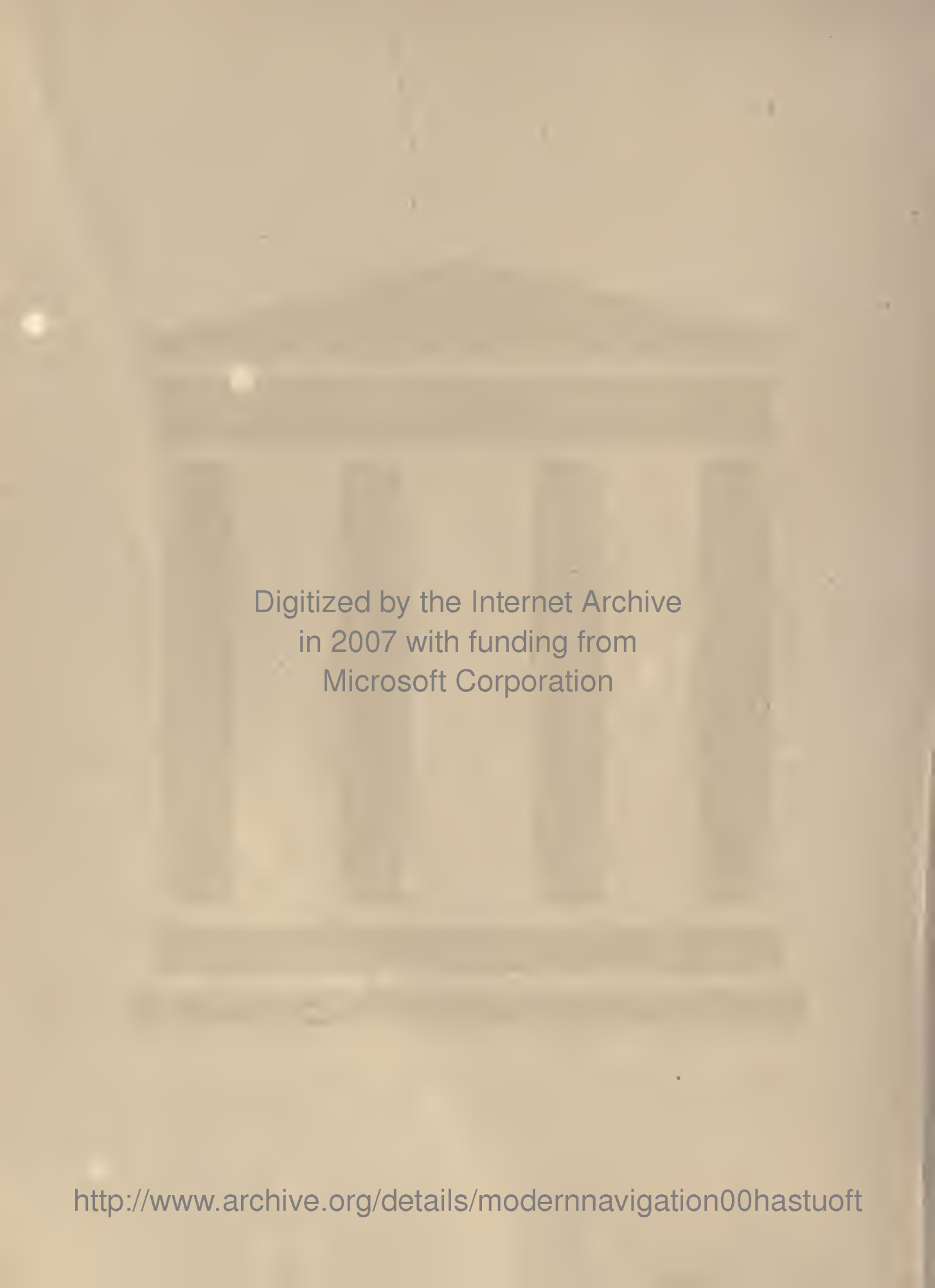
To

COMMODORE E. C. BENEDICT

Veteran Yachtsman

Whose yachting record of 400,000 miles has made him preëminent among deep sea yachtsmen. A royal host, who has given pleasure to so many friends; to him, by one of his frequent guests and many admirers, this book is dedicated in affectionate and grateful memory.

The Author.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AUTHOR'S PREFACE

THE exigencies of war seem to have disclosed a decided line of demarcation between the navigation methods in use in the Navy and those prevailing among the Merchant Marine. In the former, lines of position, worked up by the Sumner or the (so called) Marcq St. Hilaire methods, are in constant use; while chronometer, or time sights are almost entirely discarded. In the latter, time sights are the prevailing method, while Sumner and St. Hilaire methods are seldom used and very little known. Hence a thoroughly competent and experienced Merchant Marine Captain is completely at a loss on board a man of war, or a transport commanded by naval officers; whereas the author has met naval officers accustomed to working Sumner and St. Hilaire who have almost forgotten how to work out a chronometer sight of the sun.

Now in the Author's recently published work

entitled "Navigation—A Short Course" the purpose was to elucidate and make plain to the novice the methods commonly in use in the Mercantile Marine, and there to stop, without attempting to go into the more complicated Navy methods; the main object, in the present emergency, being to educate the largest possible number in the shortest possible time. As that elementary book seems not only to have accomplished its purpose as a text book for beginners, but is being widely used among Naval Officers who are rusty in the old methods and desire to "brush up," the author has been persuaded to make a similar effort with a view to present the more complicated Navy methods in an elementary form that will clearly elucidate these methods for the benefit of the old-fashioned every day navigator, as well as for the student preparing for the Navy.

The student has already learned that in order to find longitude accurately by a time sight the latitude must be definitely known. In other words, a material error in the latitude by dead reckoning (as it is generally computed) would seriously affect the longitude by a time sight.

Hence, in order to present a comparison of the methods in question, this work will be divided into three parts; first, the Merchant Marine method of determining longitude when the latitude is uncertain (commonly known as the "back and fill process"); second, the Sumner method, with its modern application; and third, the so called Marcq St. Hilaire method which is regarded by some writers as a modification of Sumner.

In the "back and fill" method, examples will be given for the purpose of illustration and also for comparison with the other two methods.

The author has found many young students who have been educated in the Navy methods but who are lacking in knowledge of the methods commonly employed in the Merchant Marine of which the "back and fill" method is fundamental and should be understood thoroughly by every navigator.

As to the Sumner method, the author's experience in teaching has led to the firm conviction that a thorough understanding of the Sumner *principle* is a prerequisite to an intelligent understanding of the Marcq St. Hilaire method;

and in this opinion the best authorities concur. For this reason a short treatise on the Sumner methods has been included in this book.

Before deciding on the general plan and scope of this brief treatise the author went to Washington for the purpose of conferring with the Hydrographic Office, and now takes pleasure in gratefully acknowledging the great courtesy extended to him by Prof. G. W. Littlenales of that most useful and highly efficient department of the Government service.

The author also gratefully acknowledges himself indebted to his highly esteemed friend and erstwhile pupil, and more recently assistant instructor, Mr. Alfred L. Ferguson, for his invaluable aid in "checking up" the problems and examples in this work.

As already stated, this work is intended to be elementary, and supplemental to the author's first book entitled "Navigation—A Short Course"; the two taken together being designed to give the broadest possible knowledge in the least possible space, eliminating a great deal that is superfluous and non-essential. The student having acquired this elementary knowledge is

urgently recommended to pursue his studies with that most admirable treatise entitled "*Elements of Navigation,*" by the author's highly esteemed friend and colleague, W. J. Henderson, A. M., Lieutenant in the First Naval Battalion of N. Y., under whose able guidance the work of instruction has been prosecuted on board U. S. S. "Granite State." This book has recently been enlarged, thoroughly revised and modernized and will be an invaluable aid to the student as well as to the experienced navigator.

INTRODUCTION

I HAVE read Commodore Hastings' work on the "Modern Navigation," and I take pleasure in commending it both to the Navy and the Merchant Marine for the dual purpose for which it is written,—to educate the merchant marine navigator in the advanced and greatly improved methods of navigation which are taught at the Naval Academy, and practiced in the United States Navy; and to elucidate these methods for the benefit of the many students who are aspirants for commissions in the Navy. The exigencies of the war have brought these two schools of navigators into close personal contact, and it is of the greatest importance that there should be a common ground on which they can work together. Commodore Hastings has had a varied practical experience in both branches of the science, and his earnest desire to educate the navigators of the Merchant Marine in the

methods used in the Navy is most praiseworthy, and cannot fail to produce results of permanent value.

The diagrams which he has prepared, and the very clear and comprehensive explanations accompanying them will, I am sure, be of great assistance to the navigator, as well as to the student.

In my opinion this pioneer work fills a widespread want in the present national emergency.

ALBERT GLEAVES.
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Commander Cruiser and Transport Force,
United States Atlantic Fleet.

CONTENTS

CHAPTER		PAGE
I.	Merchant Marine Methods	1
	Example in Latitude	5
	Example in Time Sight	6
	Example in Dead Reckoning	7
II.	Sumner Method	8
	Sumner Method—A	11
	Sumner Method—B	12
	Sumner Method—C	19
	Sumner Method—D	22
	Sumner Method—E	24
III.	St. Hilaire Method	31
	Hour Angle of Sun	36
	St. Hilaire—Rule	37
	St. Hilaire—Example	39
	Sun and Moon Simultaneously	55
	Stars by St. Hilaire	57
	Hour Angle of a Star	58
	Star by St. Hilaire—Example	60
	To Find Star's Azimuth—Rule	63
	To Find Star's Azimuth—Example	64

CHAPTER PAGE

Star's Altitude by St. Hilaire—Example 65
Simultaneous Altitude of Two Stars 67
Compass Courses 74
Correcting Line of Position by D. R. 76
Plotting Charts 76

IV. A Warning 78

MODERN NAVIGATION

CHAPTER I

MERCHANT MARINE METHODS: A PROBLEM

A VESSEL at sea has had two or three days of cloudy weather and fog during which time no observations of any kind have been possible. The weather clears early one morning, too late for the stars, and the sun comes out. The dead reckoning has been too uncertain to enable the navigator to estimate the latitude nearly enough to compute the longitude with any degree of accuracy. In the Merchant Marine, where Sumner and St. Hilaire methods are unknown (or unused) the navigator invariably proceeds in accordance with the following:

RULE

Take an early observation of the sun when it is as near as possible to the "prime verti-

cal'' (i. e., bearing due East or West from the ship's position) and at the instant of the observation get the exact Greenwich time by the chronometer. We will call this 8:30 A. M., local apparent time. Don't work this out until after you have ascertained your latitude at noon. Meanwhile calculate the course by D. R. and instruct the officer of the watch to keep his eye on the compass and see that the quartermaster steers the prescribed course with the utmost degree of accuracy. It is equally important to keep an accurate record of the distance run, either by taffrail log or by the revolutions of the engines.

N. B. The navigator should always know, by practical experience with his own particular vessel, which of the two methods for computing distance run is the more accurate. He must also know, with equal accuracy, the exact compass error. To be sure of this the watch officers should be instructed to take azimuths during each and every watch, if possible.

When noon comes the navigator will take the usual meridian observation for latitude and it is important that one or more officers should

observe with him so as to be sure of the latitude at noon.

Now take your course and distance run since the time of your morning sight, and by dead reckoning (using the traverse tables) ascertain your latitude at the time of the morning sight. Then, with the altitude and G. M. T. recorded work up the longitude and you will have the exact position of the ship at 8:30 A. M.

Again take your traverse tables and, with the course and distance run for 3½ hours, ascertain the difference of longitude between 8:30 A. M. and noon. Apply this difference of longitude to the longitude at 8:30 A. M. and you will have your longitude at noon. Thus you have what is commonly called a "fix"; i. e., your exact position, both latitude and longitude, at a given time.

There is another method quite frequently used, by navigators in the Merchant Marine, under conditions similar to the foregoing. Work up the morning sight by using a latitude computed as closely as possible by dead reckoning. This will give the *approximate* longitude at 8:30 A. M. Then when the *true* latitude at the

time of the morning sight has been found, use the new Bowditch Table 47 to correct the longitude "due to a change of latitude"; i. e., the error in latitude used to work the A. M. sight. This will give the true longitude at 8:30 A. M., which may then be brought forward to noon as herein before explained.

The example which follows is intended for those who are not entirely familiar with the "back and fill" method; but those who already understand it are recommended to skip the following pages and go on to page 8.

Example

A cruiser, doing coast patrol duty, is taken off shore chasing a submarine. After several days of fog and cloudy weather she desires to return to New York. She has had no observations of any kind for several days and her dead reckoning is very uncertain. On the morning of April 6, 1917, the sun comes out. At about 9 o'clock, A. T. S., an altitude of the sun is taken at 38° 13′; height of eye 40 feet. The chronometer reads 1 hr. 35 min. 50 sec. (P. M.) chron. error, 29 sec. slow. But, as the latitude is not

known exactly, the sight is not worked out (for longitude) until after the noon observation. From the position computed as nearly as possible by D. R. the vessel is put on the estimated course for Ambrose Channel. At noon a meridian observation of the sun is taken and the altitude found to be 59° 12′ 10″ S. Height of eye, 40 ft.; chronometer 4 h. 37 m. P. M. Hence,

Observed altitude	59° 12′ 10″ S.
Alt. corr.	09′ 18″
T. C. A	59° 21′ 28″ S.
	90°
Zen. dist.	30° 38′ 32″ N.
Corrected declin.	6° 25′ 00″ N.
Latitude at noon	37° 03′ 32″ N.

Since the morning sight was taken, at 9 o'clock A. T. S., the ship has steamed on a course of N. 42° W. at an average speed of 15½ knots. Working back from the ascertained latitude at noon we get the following:

Latitude at noon (say)	37° 3′ 30″ N.
Deduct—3 hours at 15½ knots = 46½ miles at a course of 42° = 34.5 miles	= 34′ 30″
Latitude at 9 A.M.	36° 29′ 00″ N.

NOTE. Table 2, Bowditch, under heading of 42° (p. 614) gives change of latitude

for.....	46 miles	34.2 M.
	47 "	34.9
Mean (46½ miles) or, 34′ 30″ as above.		34.5 M.

With the true latitude at 9 A. M. work out the morning time sight as follows:

T. C. A.	38° 21′ 41″		Obs. alt.	38° 13′
Lat.	36° 29′	sec. .09473	Corr. 40 ft.	08′ 41″
Polar dist.	83° 38′	cosec. .00269	T. C. A.	38° 21′ 41″
	2)158° 28′ 41″		Chron.	1 h. 35m. 50s.
			Slow	29 s.
½ Sum T. C. A.	79° 14′ 20″	cosin 9.27117		1h. 36m. 19s.
(—)	38° 21′ 41″		Equa. (—)	02m. 33s.
Rem.	40° 52′ 39″	sin. 9.81588	A. T. G.	1h. 33m. 46s.
				A. T. S.
		Havers. 19.18447	=	8h. 55m. 50s.
		A. T. G.		1h. 33m. 46s.
			Longitude in time	4h. 37m. 56s.

Giving longitude at 9 A. M. 69° 29′ W.

With the correct longitude at 9 A. M. work it up to noon, by use of the traverse Tables as follows:

Longitude left at 9 A.M.	69° 29′ W.
3 hours at 15½ knots on a course of 42° = Departure 31′ with a middle lat. of 37°, long. =	39′
Giving longitude at noon	70° 08′ W.

Now we have the correct latitude and longitude at noon and we want to find the course and distance to the Ambrose Channel light ship by middle latitude sailing—or preferably by Mercators (Bowditch Table 3) as follows:

Lat. left	37° 03′ 30″	Long. left	70° 08′
" sought	40° 28′	" sought	73° 50′
Differ lat.	3° 24′ 30″	Differ long.	3° 42′
= 205′		= 222′	
Meridional parts lat. left			2382.3
" " " sought			2644.2
Meridional differ. lat.			261.9

Which gives:

Distance	267 miles
Course	N. 40° W.

NOTE. Excepting on courses nearly E. or W. Mercators is preferable to Middle Latitude sailing.

CHAPTER II

THE SUMNER METHOD

THIS method takes its name from Capt. Thomas H. Sumner, an American Shipmaster who, having sailed from Charleston, S. C., Nov. 25th, 1837, bound for Greenock, found himself approaching the coast of Ireland in a heavy Southerly gale with cloudy weather and no means of determining his position.

At 10 A. M. the sun appeared and he took an altitude and noted the Greenwich time; but as his latitude was uncertain he could not be sure of his longitude by chronometer. Nevertheless he worked out the sight with an assumed latitude (by D. R.) and the result gave him a position 15′ East of his position by D. R. He then assumed a second latitude 10′ North of the one by D. R. and dotted this position on the chart. Next he assumed a third latitude 10 miles South of his D. R., worked it out and dotted this 3rd

position on the chart. Then he drew a line from the 2nd to the 3rd position and found that it ran through the 1st position worked by D. R. In other words the three positions were found to be in a straight line. He therefore deduced that no matter what latitude he assumed (within reasonable limits) his ship must be located somewhere on that line or on an extension thereof. He then extended that line on the chart and found that it ran through Small's light.

The line bore E. N. E. and he immediately put the ship on that course. In about an hour he made the light, practically dead ahead.

This line has since become known as a Sumner line or "line of position." But a single Sumner line, while of great value, does not give the exact position of the ship; only a line upon which she is somewhere located. Capt. Sumner's next step was to wait about two hours after drawing the first "line of position," or until the sun's azimuth had changed about two points. Then the same operation was repeated; that is, he took a chronometer sight of the sun and worked out the longitude with an assumed latitude 10 miles North of his D. R. and dotted that position on

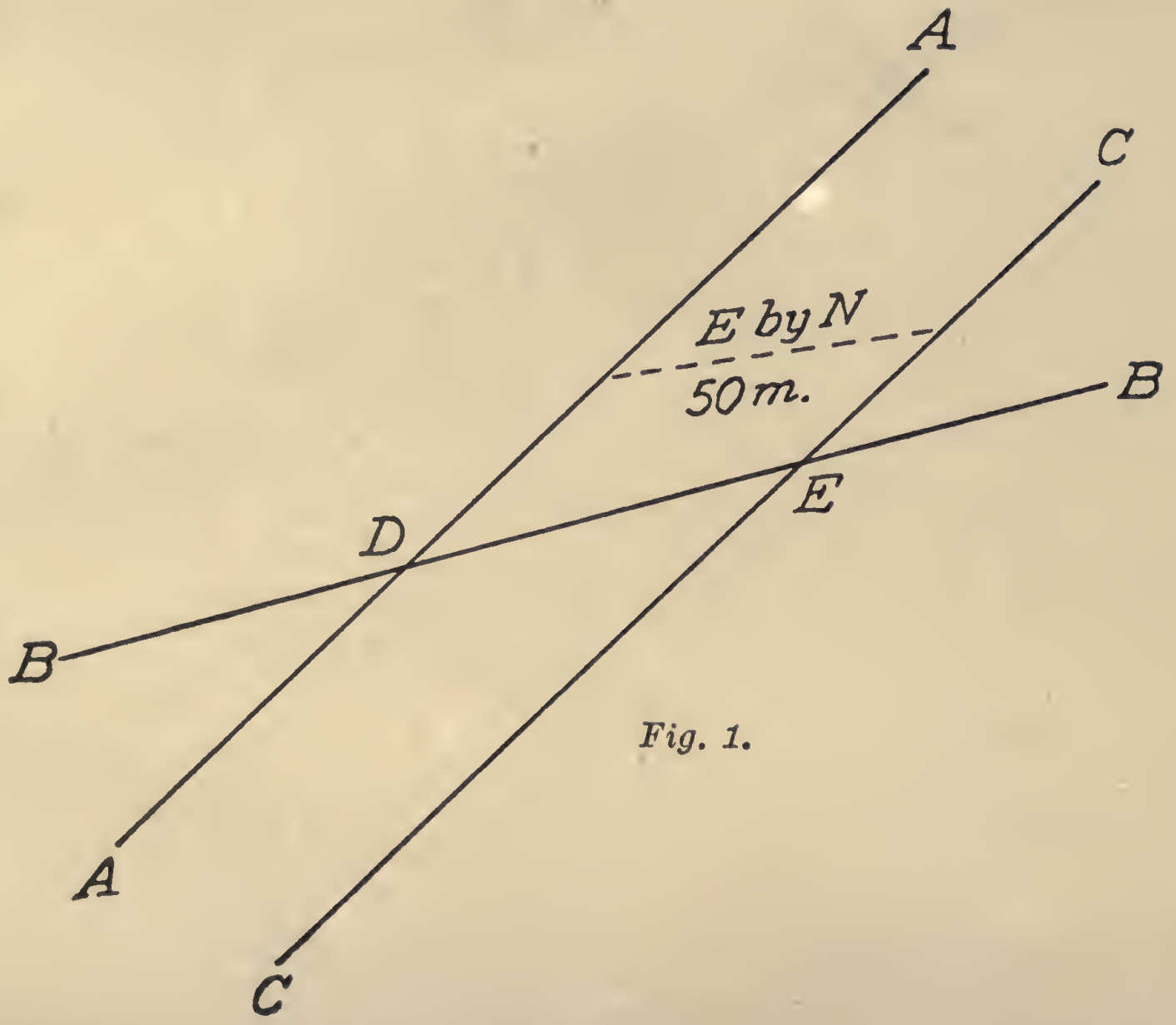


Fig. 1.

the chart. Then he worked his longitude from the same sight but assuming a latitude 10 miles South of his D. R. and dotted that position on the chart. Then he drew a line between these two points and found that this second line crossed the first line of position and therefore the point of intersection of these two lines would have been the approximate position of the ship at the time of the first sight, if she had been anchored, or standing still. Now between the first and second sights the ship had sailed E. by N. 50 miles and he therefore moved the first line along 50 miles at E. by N. and drew a third line parallel to the first and the intersection of this third line with the second gave the position of the ship at the time of the second sight, according to the following diagram which we will call

Sumner Method A

Fig. 1

A A=first line of bearing
B B=second line of bearing
C C=first line moved along 50m. parallel to itself
E=position at 2nd sight

NOTE. The course and distance (E. by N. 50 miles) may be projected *from any part* of the first line of bearing so long as the line C C is laid out from the terminus of the course and drawn parallel to the first line of bearing.

This original Sumner method, however, has become obsolete because it involves working out four chronometer sights—an unnecessary amount of labor. The method now most generally in use we will call

SUMNER METHOD B

By this method the Sumner line is obtained by dotting the ship's position on the chart and from that position draw a line representing the true azimuth of the sun at the instant the observation was taken; and at right angles to that line, through the position of the ship, draw another line which will be the Sumner line, or line of bearing, at some point of which the ship must be located. Thus:

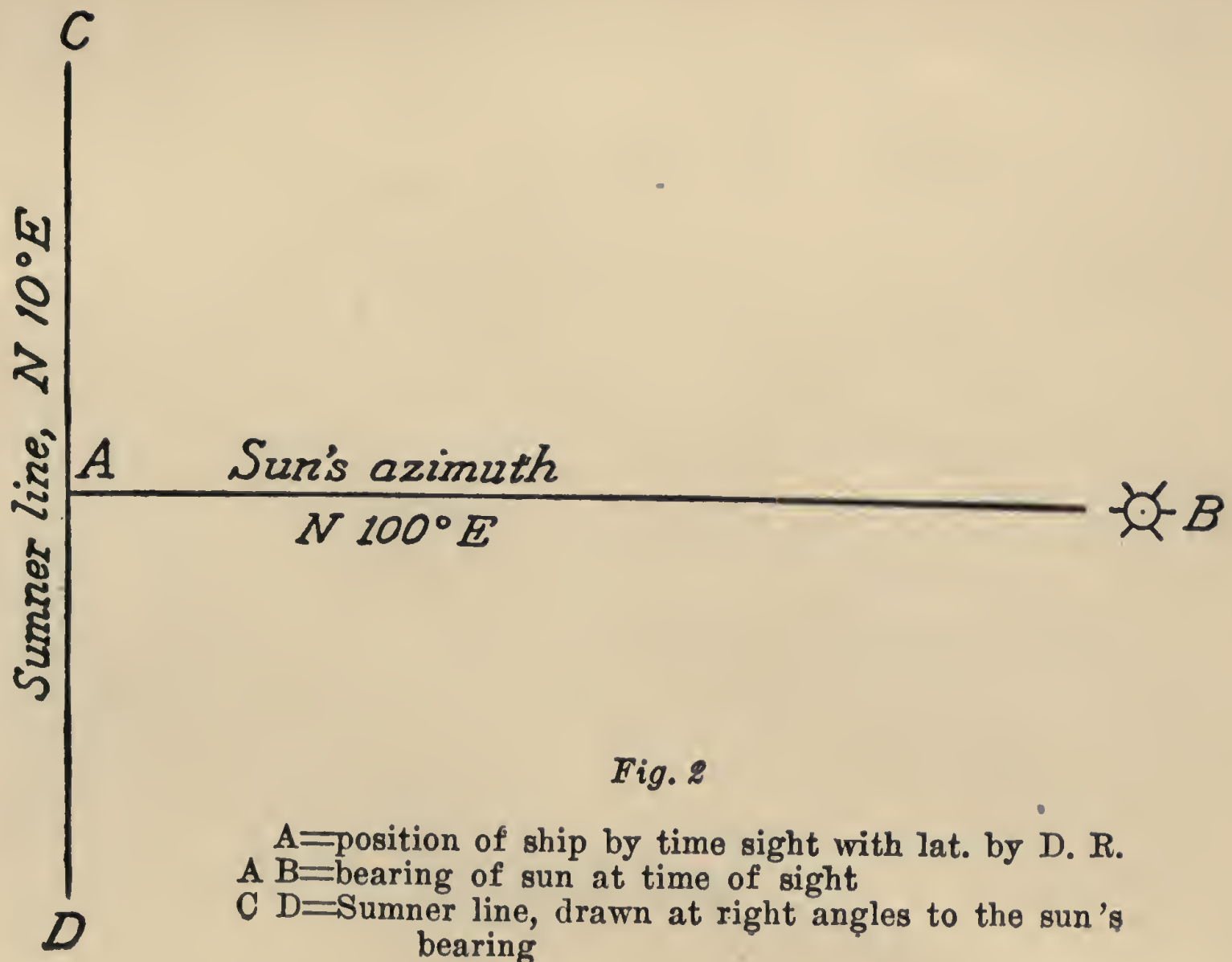


Fig. 2

A=position of ship by time sight with lat. by D. R.
A B=bearing of sun at time of sight
C D=Sumner line, drawn at right angles to the sun's bearing

The ship's position (A) is of course first obtained by taking a chronometer sight of the sun and working it out with latitude by D. R. But, in this way, the Sumner line is found by working up only *one* chronometer sight instead of two, as in the first method described (A).

The principle of this simple diagram should be understood clearly.

The Sumner line is supposed to be a straight line, and for all practical purposes of navigation it *is* a straight line. But, in reality, it is part of a great circle of which the sun is the center and the bearing of the sun the radius. The Sumner line is, of course, tangent to the periphery of the circle and at right angles to the sun's bearing. The following simple diagram (from Bowditch) will illustrate (Fig. 3):

A represents the ship's position. Then A B is the sun's bearing and D E the Sumner line, drawn at right angles to the sun's azimuth and tangent to the periphery of the circle at A, the ship's position. In the smaller circle, the line A C is the sun's bearing and F G the Sumner line.

Or, as Bowditch states it: "Since the direc-

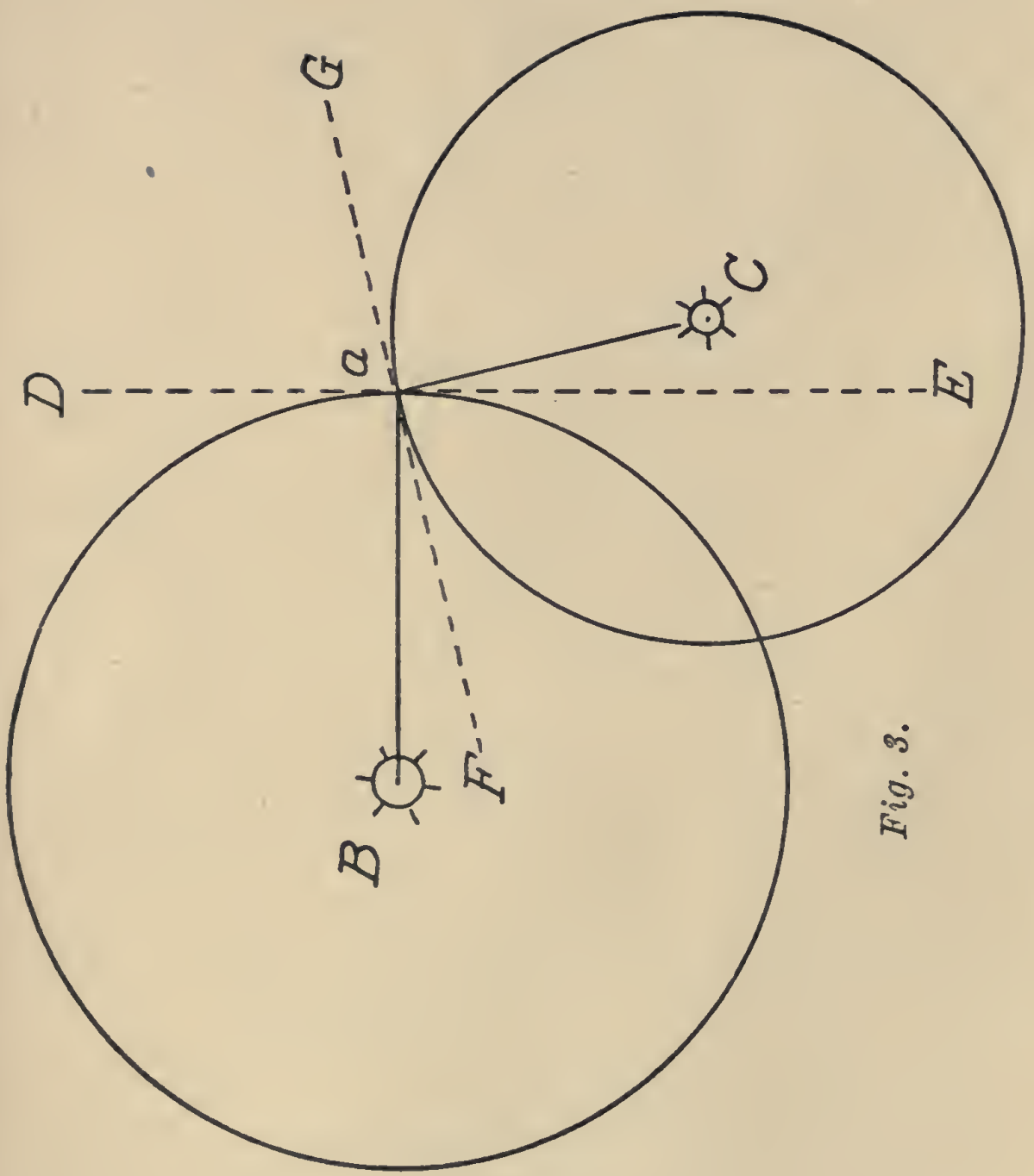


Fig. 3.

tion of a circle, at any point—that is, the direction of the tangent—must be perpendicular to the radius at that point, it follows that the Sumner line always lies in the direction at right angles to that in which the body bears from the observer.''

Hence it is plain that if we take the azimuth of the sun from the ship's position at *any* point, draw that line on the chart and draw another line at right angles to it, this second line, drawn through the ship's position, will be the Sumner line, on some point of which the ship is located.

The fact must be emphasized that the circle is so great that any small portion of it, projected on the chart, must be a straight line, for all practical purposes; and that line (the Sumner line) must be at right angles to the radius (the sun's bearing) and tangent to the circle itself. We are now ready to consider the second method (B) as illustrated by the diagram, Fig. 4:

Take a chronometer sight at 8 A. M. and work it out with latitude by D. R.

Plot this position on the chart (at E). With the apparent time at ship, found by the observation, get the true azimuth (compass bearing)

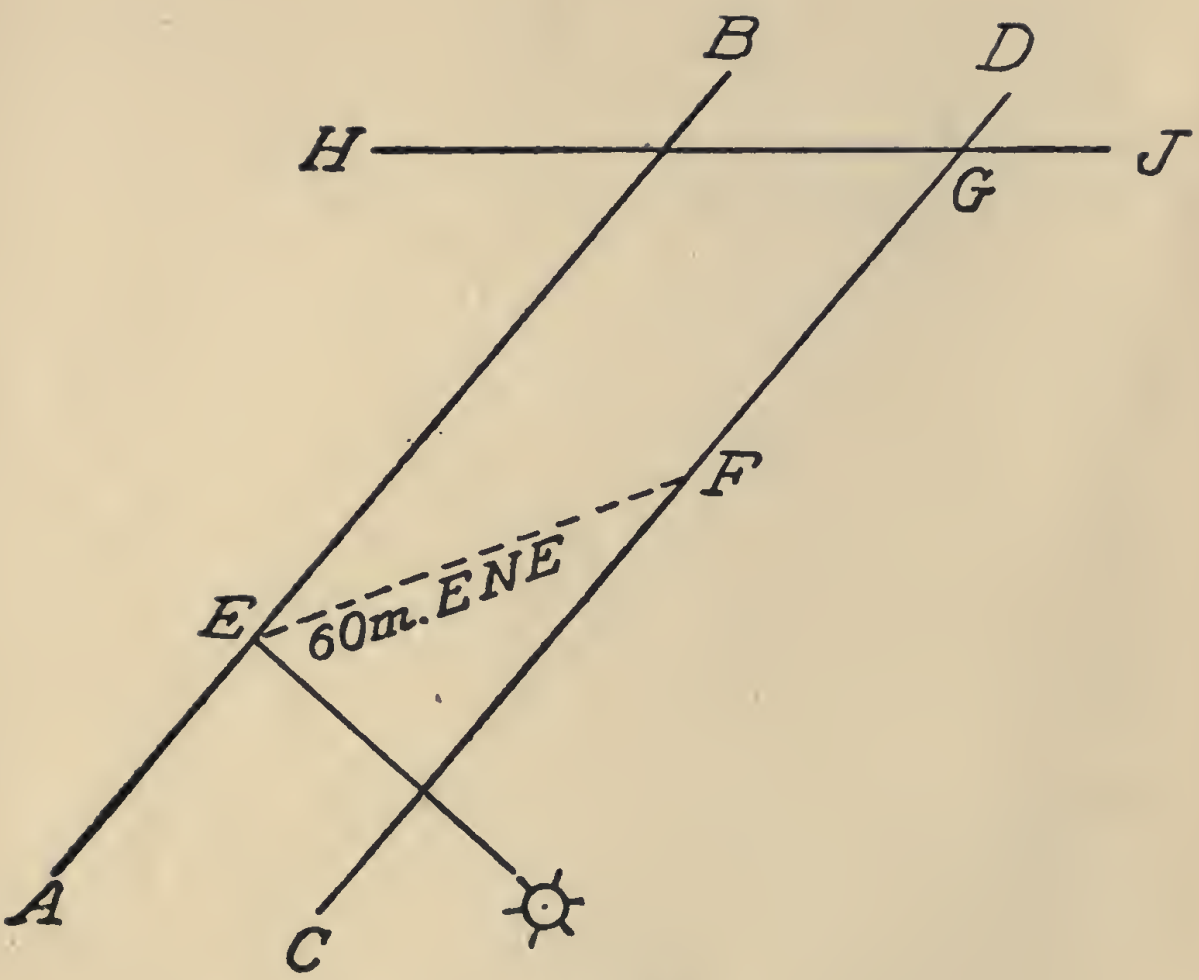


Fig. 4

E=estimated position at 8 A. M.
E to ⊙=azimuth
A B=Sumner line
C D= " advanced
H J=latitude at noon
E F=course sailed
G=position at noon

of the sun and lay it out on the chart from the dotted position E. At right angles to this line plot the Sumner line, A to B. Wait till noon, get the latitude by meridian observation of the sun and plot the line H J, bearing East and West on the ascertained noon latitude. From the time of the morning sight the ship has sailed E. N. E., 60 miles. Plot this course on the chart, (E to F) and through F draw the line C D parallel to the Sumner line A B. This will be the advanced Sumner line (C F D) and where it intersects the line of noon latitude (G) will be the position of the ship at noon, the longitude, of course, being thus shown by the diagram on the chart.

This method, requiring, as it does, only one chronometer sight, seems to be the one now most generally in use at sea, when the ship is well off shore. The time required, however, is the same as the "back and fill" process; i. e., from time of morning sight until noon.

By taking *two* chronometer sights the latitude and longitude may be determined much earlier, depending on the time of the first sight. After the first sight about two hours should elapse

before taking the second sight, or until the sun's azimuth has changed two points (about 23 degrees). Hence if the first sight be taken as early as 7:30 A. M., and the second at 9:30 the correct longitude may be determined before 10 o'clock.

We will call this method:

Sumner Method C

By two chronometer sights and two azimuths of the sun.

Take an early morning chronometer sight, and work it out with latitude by D. R. From the position thus obtained find the true azimuth of the sun and through that point (or position) draw a line at right angles to the sun's bearing. This will be the first Sumner line, A A. Wait about two hours, or until the sun has changed its azimuth two points or about 23 degrees and then repeat the operation, taking a second chronometer sight (with latitude by D. R.) and dot this second position on the chart. With the sun's azimuth, plot another line through this second point, or position, at right

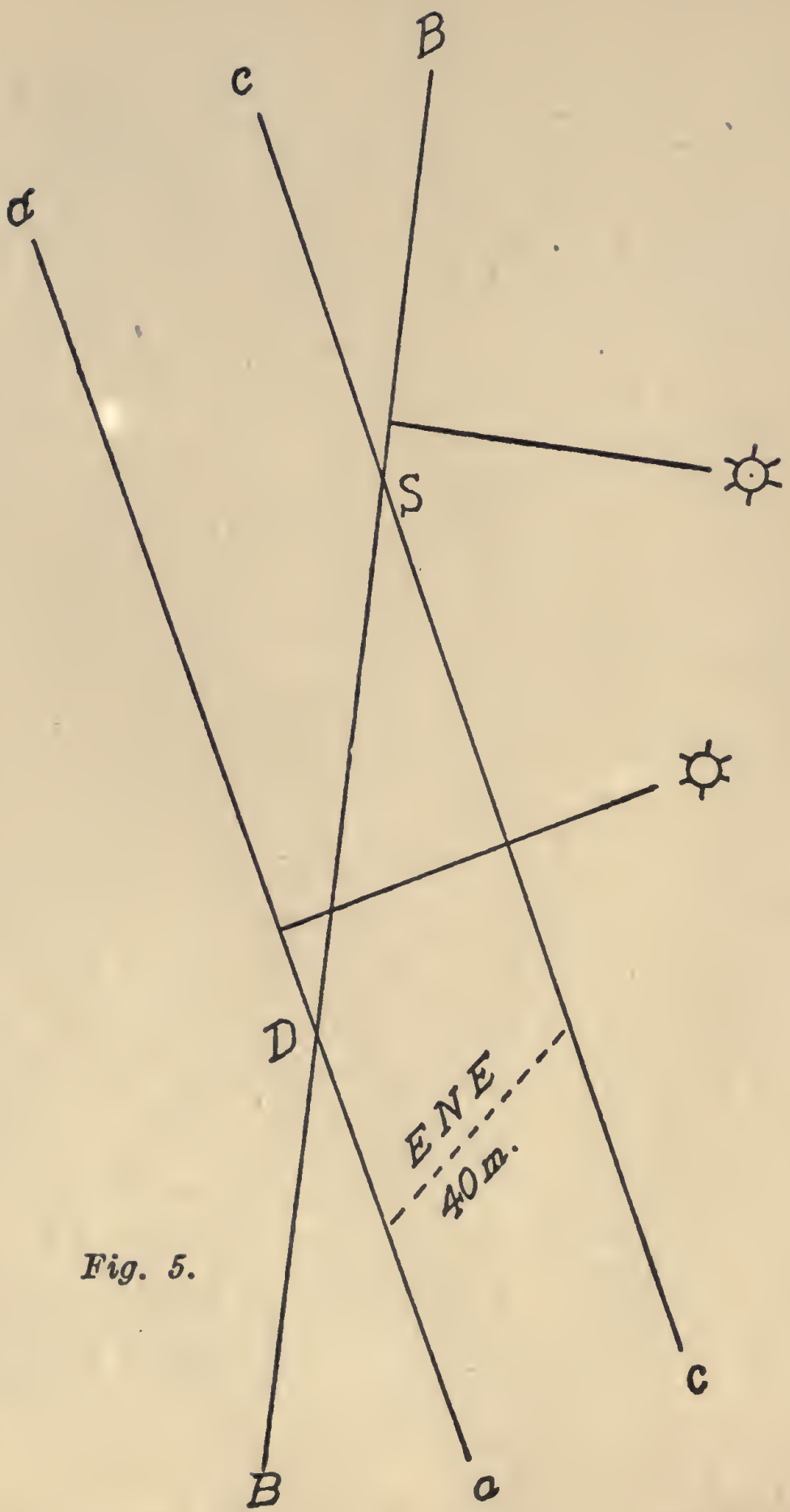


Fig. 5.

angles to the sun's bearing, the line B B which will be the second Sumner line and which will intersect the first Sumner line.

The ship meanwhile has sailed E. N. E. 40 miles. Now extend the first Sumner line E. N. E. 40 miles and draw a line parallel to it (C C). At the point where this extended line intersects the *second* Sumner line (S) will be the ship's position at time of the second sight. Thus the latitude and longitude are found at least two hours before noon.

This method, requiring two chronometer sights, is desirable only when, because of the ship's proximity to land or for some other reason, the navigator wants to get his position as early as possible, without waiting for noon.

Fig. 5

A A=1st Sumner line
B B=2nd Sumner line
C C=1st Sumner line extended E. N. E. 40m. and drawn parallel to it
S=position at 2nd sight

N. B. Course and distance may be projected from any point on 1st Sumner line.

There is another method, involving morning and afternoon sights, which is particularly valuable when, as often happens, the weather "clouds up" shortly after taking the first morning sight and the sun remains obscured until after noon so that no meridian observation at noon, for latitude, has been possible. This we will call

Sumner Method D

Take a morning chronometer sight, work it out with latitude by D. R. and find the sun's true azimuth at time of sight. The sun goes under and does not appear in time for the usual noon observation, but comes out early in the afternoon. Then take an afternoon chronometer sight, work it out with latitude by D. R. and find the sun's true azimuth. The following diagram will illustrate this method.

The A. M. chronometer sight put the ship at P which gives the 1st Sumner line A B. The afternoon sight gives the second Sumner line E F. Between the two sights the ship sailed South 58 miles, so the advanced Sumner line C D is drawn parallel to the first. The inter-

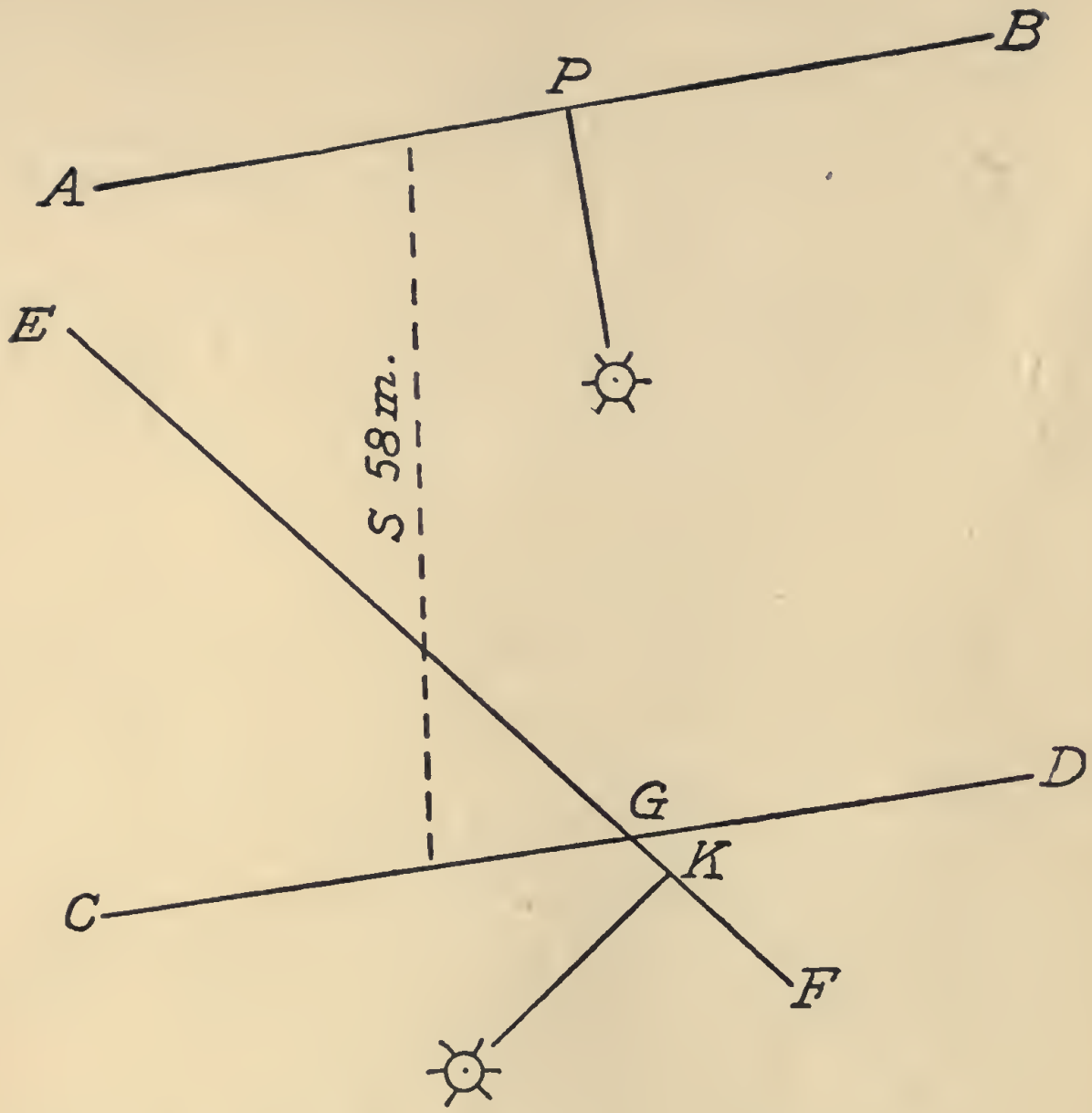


Fig. 6

P=1st position by chron. sight with lat. by D. R.
A B=1st Sumner line
C D=advanced parallel to A B
K=2nd D. R. position
E F=2nd Sumner line
G=position at time of 2nd sight

section of this advanced line (C D) with the second Sumner line (E F) gives the ship's position at G, at time of the second or afternoon sight.

This method is not often used because of the time required. But its value will be obvious under certain conditions, as above suggested.

Sumner Method E

There is another method, involving only a single sight, the use of which the author urgently recommends when approaching land. For example, a ship is bound from Bermuda to New York and has laid her course, as nearly as possible, for a point near the Scotland Lightship. An afternoon chronometer sight places her at A in the diagram (Fig. 7).

At the instant the sight was taken, the sun's azimuth was found to be N. 135 W. or S. W. from the ship's position at A, which, of course, is uncertain. Through this point, at right angles to the sun's bearing, a Sumner line is drawn and projected to the coast (F A D). We know that she is somewhere on that line. Now

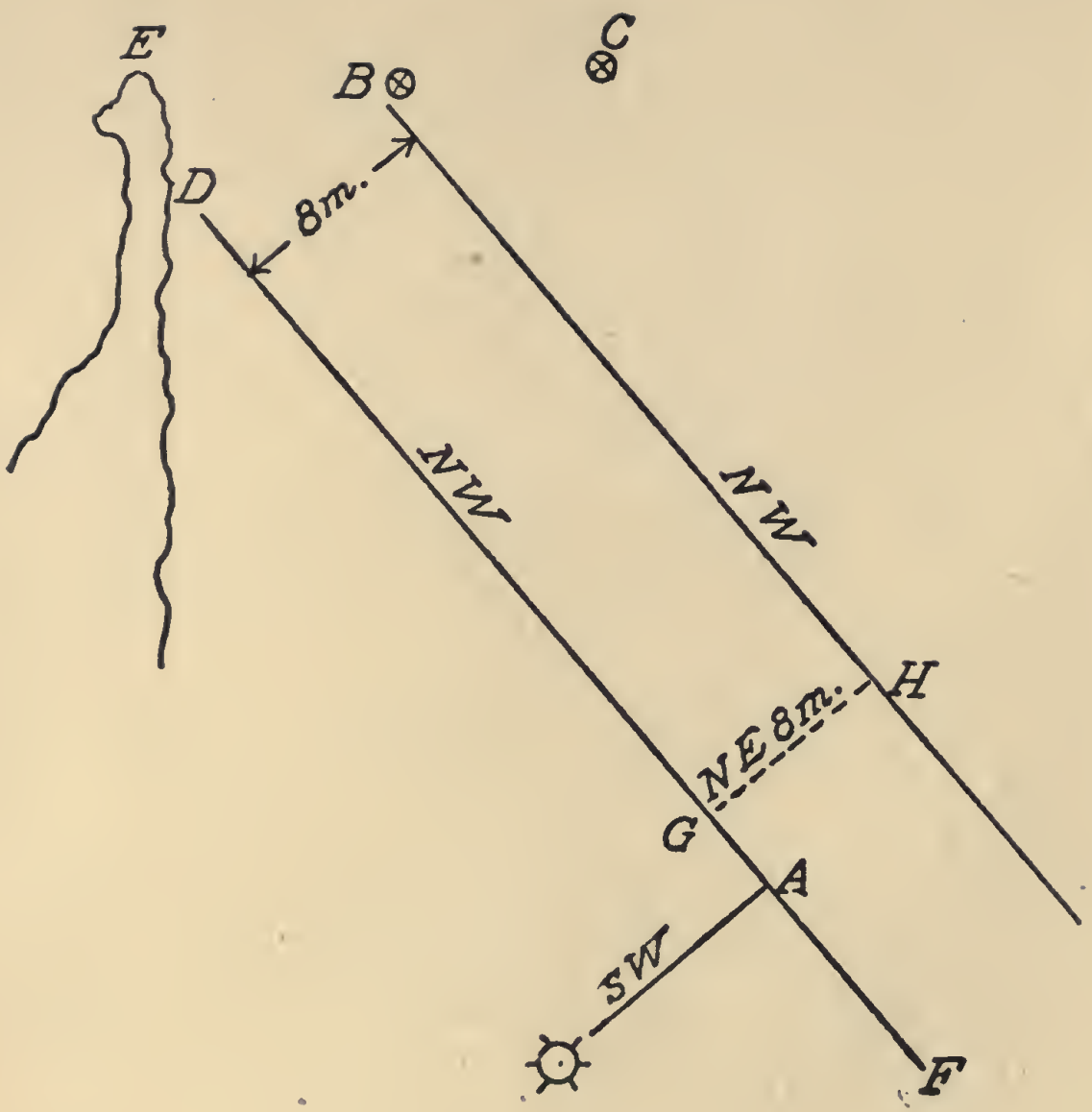


Fig. 7.

A=ship's position by D. R.
D=point on Jersey beach.
E=Sandy Hook
B=Scotland Lt. Sh
C=Amb. Cham. Lt. Sh

it is apparent that if the ship sails on that line she will "fetch up" on the Jersey beach at D.

Using the dividers on the chart it is found that the ship is say 8 miles to the S. W. of her proper line of position or course. She therefore changes her course at once and steers, at right angles to the Sumner line, N. E. 8 miles (G to H) and at H changes her course to N. W. which will take her directly to the Scotland Lightship at B, as will be plainly seen by an examination of the diagram.

The student is urged to study this method as one that insures safety in making land. It is easy and is done quickly. Simply get the sun's azimuth and, on the chart, project the Sumner line to the coast, from which the proper course to the desired point of destination will be easily and quickly ascertained.

Sumner Methods Recapitulated

There are, of course, many and various conditions under which the principles of the Sumner line may be applied; but the five methods herein described, if carefully studied, will be

ample to give the student a sufficient understanding to enable him to adapt and apply the method to the varying conditions in which the navigator may find himself.

Reviewing these five methods:

Method A, as already stated, is practically obsolete because of the time required to work out four chronometer sights in order to get two Sumner lines. In the other methods the same result is accomplished by drawing a line at right angles to the sun's true bearing.

Method B. This is the simplest and easiest of all the methods because it requires the working out of only *one* chronometer sight, the Sumner line thus found being extended to intersect the line of latitude at noon. This seems to be the method most generally used, although it necessitates waiting till noon to get a definite fix. This does not seem to matter, however, so long as the vessel is well off at sea. If, on the other hand, land is near by, the navigator would do better to use

Method C. By this method it is necessary to work out two chronometer sights but the posi-

tion may be found by about ten o'clock, or two hours before noon.

Method D. This method is not necessary when it is possible to get a second morning sight within say two hours from the first. But, if the sun is obscured after the first morning sight, and comes out again in the afternoon this method is very valuable although great care should be exercised with the dead reckoning on account of the long run between the two sights.

Method E is used for an entirely different purpose from any of the others and, as the diagram shows, is available only when making land.

This last method may also be used for identifying permanent land marks when approaching a coast, thus

Fig. 8

A=peak
B=peak
C D=coast line
E F=line of bearing at right angles to sun's azimuth
F=ship's position

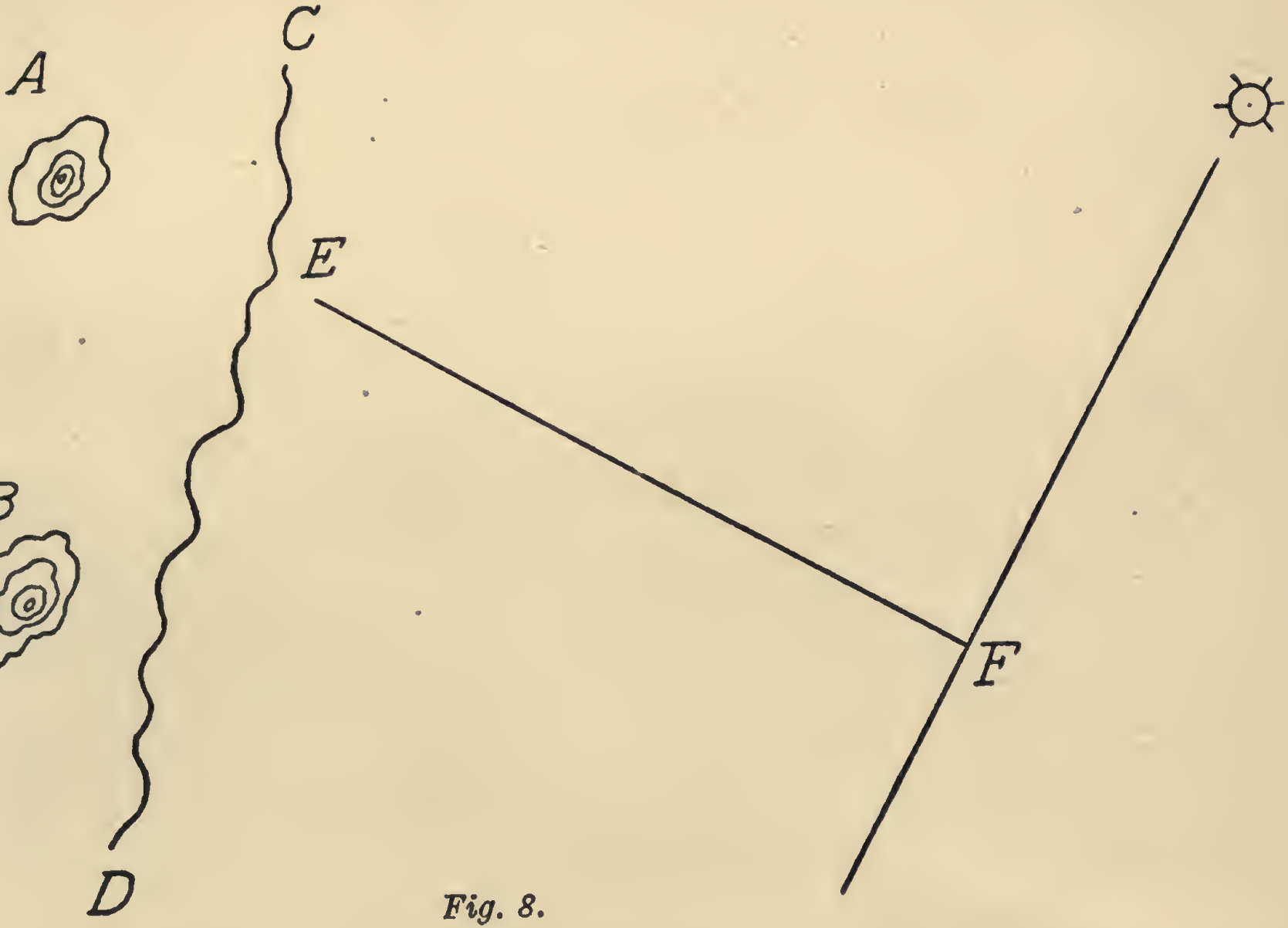


Fig. 8.

NOTE. All of the foregoing methods may of course be used with stars, planets or moon as well as with the sun.

In presenting these various Sumner methods to the student the author has been convinced that a thorough knowledge and understanding of the Sumner principle is, or should be, a condition precedent to the study of the now widely used method of Marcq St. Hilaire which latter is practically a modification of, and an improvement on, the Sumner principle. We will first consider its theory and then give examples of its practice.

CHAPTER III

MARCQ ST. HILAIRE METHOD

THE principle of this method is to lay down on the chart a Sumner line through the position by dead reckoning, and at the moment the ship is on that position take an altitude of the sun with a sextant, apply the altitude correction and call this the *true* altitude. Then ascertain what the altitude *would have been* to make that D. R. position and call this the *computed* altitude. Now if the *computed* altitude and the *true* altitude are exactly alike, the D. R. position must be correct. But there is generally a difference; and if the *true* altitude is higher than the *computed* altitude the ship is nearer the sun, using the sun's bearing as a course. If, on the other hand, the *true* altitude is *lower* than the *computed* altitude the ship is further away from

the sun, using an extension of the sun's bearing (away from the D. R. position) as a course. One advantage of this method is that all of the calculations may, if desired, be made before the D. R. position is reached; so that when the true altitude is found with the sextant the navigator has only to compare it with the computed altitude (already worked out) and the new Sumner line is drawn. (See Fig. 9.)

Early in the morning it is decided to take an observation at eight o'clock. By D. R. it is predetermined that the ship's position at eight o'clock should be at C.

From the azimuth tables it is found that at that time the sun's bearing will be N. 105° E. Hence the first Sumner line, A A, is plotted on the chart. It is also calculated in advance that in order to make the D. R. position at eight o'clock the sextant should give an altitude of 22° 46′, which is the "computed" altitude determined in advance. When eight o'clock comes, an observation with a sextant shows the *true* altitude to be 22° 53′, or 7′ higher than the computed. Hence the ship is seven minutes of

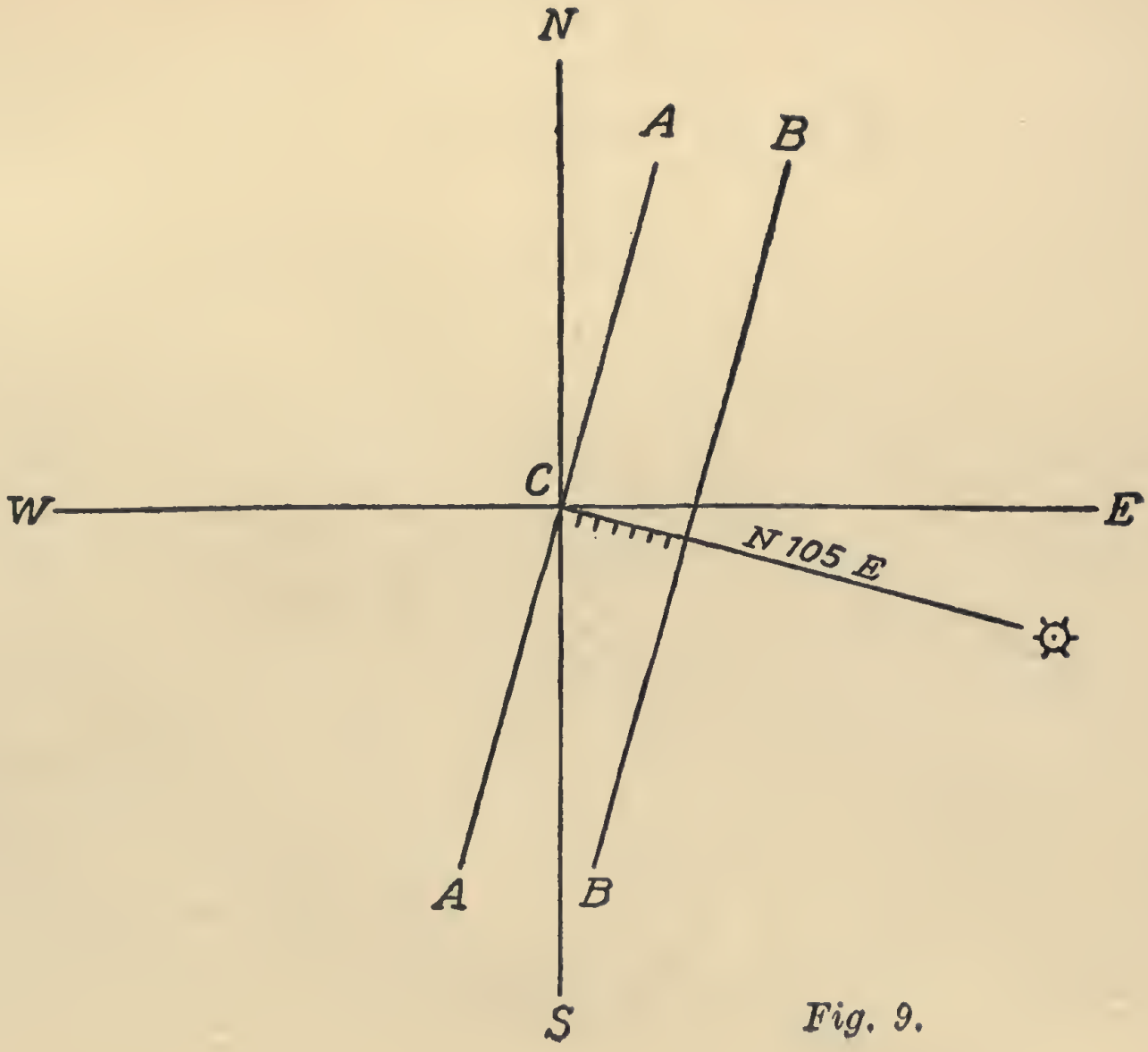


Fig. 9.

arc nearer the sun, using the sun's bearing as a course. This is measured on the chart and the new or corrected Sumner line is drawn, B B.

Or, if the sextant observation had shown a *true* altitude of 22° 39′, or 7′ *lower* than the computed altitude, then the position should be moved away from the sun, extending its bearing as a course, thus (Fig. 10):

C=D. R. position. A A, first Sumner line. B B, second or corrected Sumner line. The only figuring that is required is to find the computed altitude for the D. R. position. Before considering the rule and working an example the student must learn how to find the azimuth of the sun and how to compute its hour angle.

The hour angle is found by calculating the local apparent time at the ship. When the observation is taken the time by the chronometer is noted and corrected for its error, fast or slow. To this G. M. T. must be applied the longitude in time, adding it if East and subtracting it if West of Greenwich. This will give the local mean time to which must be applied the corrected equation of time which will give the local

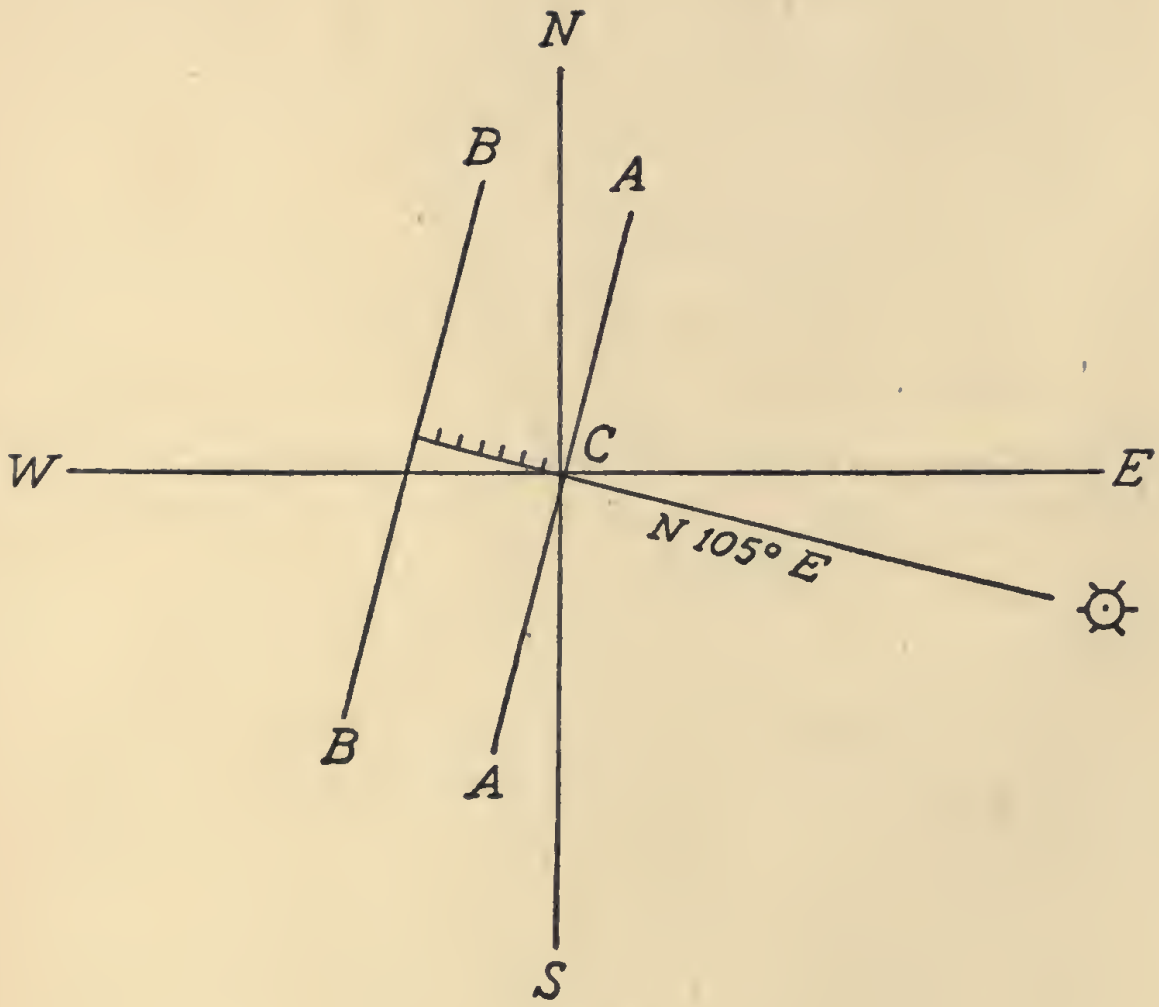


Fig. 10.

apparent time (or H A). Now with this local apparent time, with the latitude by D. R. to the nearest degree and with the sun's declination to the nearest degree, or the date, go to the azimuth tables and find the true azimuth at time of sight.

The Hour Angle of the sun is the difference between the observer's meridian and the meridian passing through the body. When the sun is West of the meridian the local apparent time is the hour angle. When it is East of the Meridian deduct the local apparent *civil* time from 12 hours or the astronomical time from 24 hours and the remainder is the Hour Angle. For example, at 3 o'clock in the *afternoon*, apparent time, the

Hour Angle is.....3 hours
At 9 A. M. civil time H. A.....3 hours
At 21 hours Ast. time H. A.....3 hours
At 7 A. M. civil time H. A.....5 hours
At 19 hours Ast. time H. A.....5 hours

Rule

From the dead reckoning position (determined in advance) at which the ship ought to be, say at 8 A. M., calculate the sun's altitude, i. e., what the altitude would be to give that D. R. position at 8 o'clock, A. T. S., by the following formula:

Find the Hour Angle and add together the following:

Log Haversine of the Hour Angle
Log Cosine of the Latitude
Log Cosine of the Declination

The sum of these logs will be a log Haversine of an arc, opposite which (in Table 45) will be found a Nat. Haversine and to this Nat. Haversine must be added the Nat. Haversine of the meridional zenith distance.

M. Z. D.=L—D, or D—L, if L. and D. are of same names.
M. Z. D.=L+D if L. and D. are of opposite names.

The sum will be the Nat. Haversine of the calculated zenith distance.

Subtract this Z. D. from 90° and the result will be the computed altitude.

NOTE. The above formula for finding the meridional zenith distance means that if latitude and declination are of the same name (both N. or both S.), we must subtract the lesser from the greater (L—D, or D—L). If the latitude and declination are of *opposite* names (one N. and the other S.) then the two must be added together (L+D).

At the same time find out from the azimuth tables what the true azimuth of the sun will be at 8 o'clock apparent time, using the declination from the almanac and the latitude from the assumed D. R. position.

Next, dot the D. R. position on the chart and from it (using the parallel rulers) draw a line to represent the sun's bearing; and at right angles to that line, through the D. R. position, draw a second line which will be the D. R. Sumner line, as described in Sumner method B, on page 12.

Now having found in advance the *computed* altitude for the eight o'clock position, wait un-

til eight o'clock and at that exact instant take an observation with a sextant, apply the altitude correction (Bowditch Table 46), which will give the sun's true altitude. Then compare the *computed* altitude with the *true* altitude and apply the following rule which should be committed to memory: if the *true* altitude is higher than the *computed* altitude the ship is *nearer* the sun than the D. R. position; but if the *computed* altitude is higher than the *true* altitude the ship is further away from the sun and the Sumner line must be moved accordingly (*see* page (?).

Now, with the foregoing rule in mind, we will consider the following:

Example

At sea, May 18, 1916, A. M. sight of the sun, Lat. 41° 33′ N., Long. 33° 30′ W. (by D. R.). Obs. Alt. 29° 41′, Ht. of eye 23 ft., Chron. 9 h. 37m. 51s. Rate 4m. 59s. slow. Equation 3m. 44s. (+). Declination 19° 31′ 24″ N.; Azimuth of sun N. 89 E.

Chron.	9h. 37m. 51s.	Obs. alt.	29° 41′
Slow (+)	04m. 59s.	Corr. 30 ft.	09′ 04″
	9h. 42m. 50s.	True alt.	29° 50′ 04″
Equation (+)	03m. 44s.		
G. A. T.	9h. 46m. 34s.		
Longitude W.	2h. 14m. 00s.		
L. A. T.: (A.M.)	7h. 32m. 34s.		
	12h.		
Hour Angle	4h. 27m. 26s.	Havers	9.48215
Lat. by D. R.	41° 33′ N.	Cosine	9.87412
Declination	19° 31′ 24″ N.	Cosine	9.97430
		Haversine	29.33057
		Gives Nat. Hav.	.21408
Lat.,-Decl'n	22° 01′ 36″. =	Nat. Hav. (+)	.03649
Meridional Z. D.	60° 04′ 30″	Nat. Hav. of Z. D.	.25057
Subtract from	90°		
Computed alt.	29° 55′ 30″		
True altitude	29° 50′ 04″		
Altitude diff.	5′ 26″ away from sun		

Latitude and declination being the same name (both N.) subtract the lesser from the greater. The true altitude being *less* than the computed (or D. R.) altitude the D. R. position is moved *away* from the sun 5′ 26″, using the extended sun's bearing as a course.

The diagram (Fig. 11) is not drawn to a scale but is given for purposes of demonstration. The horizontal and vertical lines represent the lati-

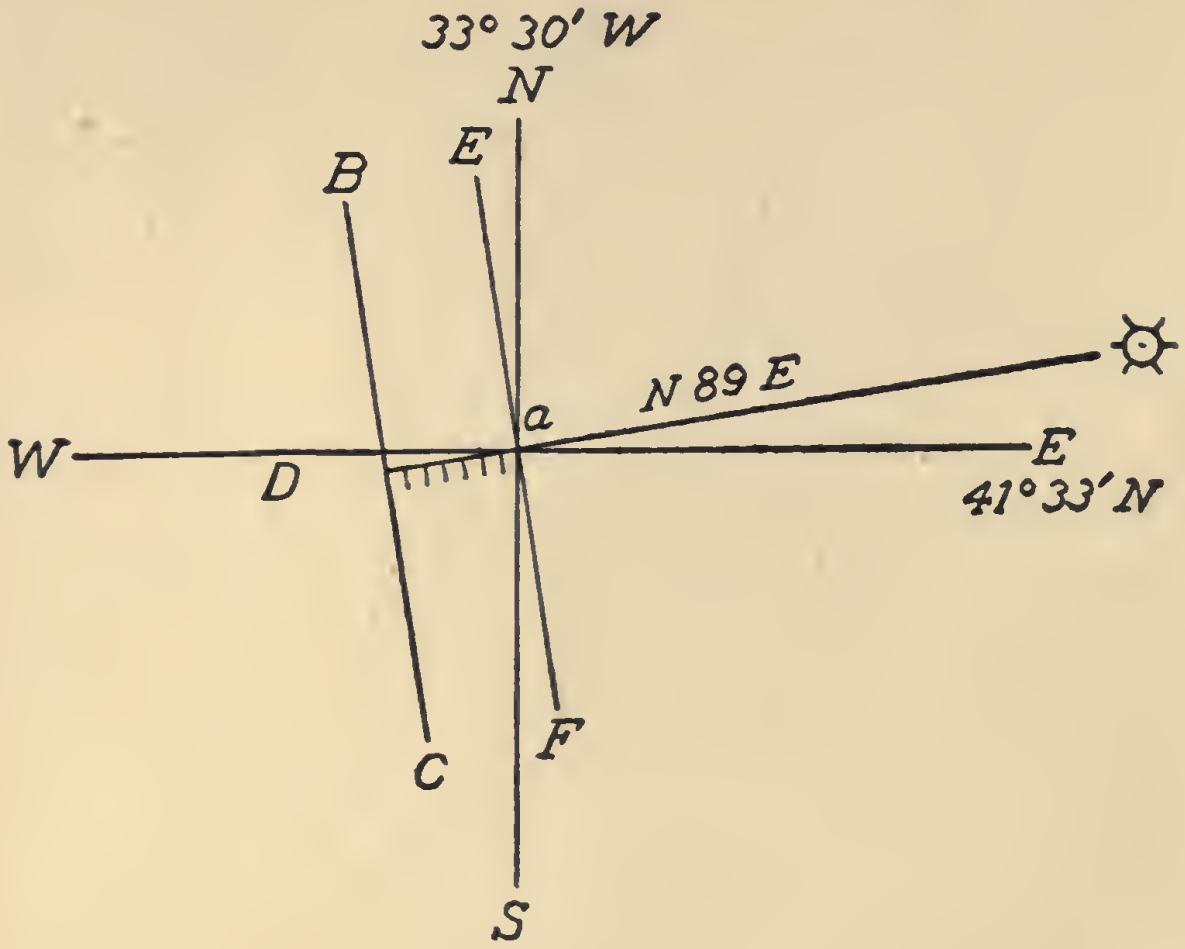


Fig. 11.

tude and longitude by D. R., the intersection, at A, being the position of the ship by D. R.

The first step, early in the morning, is to determine in advance, by dead reckoning, what the position of the ship will be at about half past seven, local apparent time. This is computed to be in Lat. 41° 33′ N., Long. 33° 30′ W., by

D. R. Dot this position on the chart. This gives, in advance of the sight, the ship's D. R. position at A. From that point project the sun's true azimuth, N. 89° E., and at right angles to that line (passing through A) draw a line at right angles to the sun's bearing. This will give the Sumner line, E F.

Now, ascertain what the chronometer will show at half past seven L. A. T. We will call it 9h. 37m. 51s. Apply the rate and the equation (corrected to time of sight) and we get 9h. 46m. 34s. which is G. A. T. As we are in W. longitude we must *deduct* the longitude in time, which gives us 7h. 32m. 34s. L. A. T. which is *not* the hour angle, as it is sometimes erroneously called, but is simply the local A. M. civil time of May 18th, which would be 19h. 32m. 34s. astronomical time of May 17th. Now as the hour angle is the distance of the sun from the observer's meridian, measured in time, we deduct the civil time from 12 hours, *or* the astronomical time from 24 hours which gives the hour angle or distance from our meridian (noon) measured in time (15° to the hour). In other words the time from 7h. 32m. 34s. to

noon is 4h. 27m. 26s. which is the hour angle.

NOTE. As a matter of interest, turn to Bowditch, Table 45 (page 864), reading from the top of the page you will find that 4h. 27m. 26s. gives the log. havers. 9.48215; and, reading from the bottom of the page, 19h. 32m. 34s. gives exactly the same log. Hence it is obvious that it is erroneous to take the A. M. civil time (7h. 32m. 34s.) as the hour angle. Table 45 gives *astronomical* time. From noon to midnight, which is P. M. civil time, read from the top of the page. From midnight on, read from the bottom of the page; and if you want A. M. civil time, deduct 12 hours from any time given at the bottom of the page.

Now, going back to our example on page 40 we take the H. A. 4h. 27m. 26s., turn to table 45 Bowditch and, reading from the top of page 864 we find the haversine of the H. A. to be 9.48215. In this table, reading from the top of the page, the seconds are given in the extreme left hand column; and, reading from the bottom of the page, the seconds are given in the extreme right hand column.

From Table 44 we find the cosine of the lat.

by D. R. and the cosine of the declination. Adding these three logs gives us the haversine, 9.33057. In Table 45, page 855, we find the nat. hav., .21408 in the nat. hav. column opposite our log. hav. of 9.33057. Then, the lat. and declination being the same name we deduct the lesser from the greater which gives us 22° 01′ 36″ of which the nat. hav. is found in Table 45 (page 828) to be .03649 (read degrees and minutes from top of nat. hav. column with fractions of the 15′ interval in heavy face type in extreme left hand column).

Following the rule, we add together these two nat. haversines, which gives us the nat. hav. of the zenith distance, .25057. Turning again to Table 45, page 859, we find that this nat. haver. gives us 60° 04′ 30″ (60° 00′ at top of column and 4½′ opposite to left) which zenith distance we subtract from 90° to get the computed altitude of 29° 55′ 30″. This *computed altitude* is what we would have found with the sextant if our assumed or D. R. position had been correct. But the altitude actually observed with the sextant, or the "*true* altitude" (after applying alt. corr.), was 29° 50′ 04″; and as this true altitude

is 5′ 26″ lower than the computed altitude we are further away from the sun than the assumed or D. R. position. Therefore as in Fig. 11 we extend the sun's line of bearing from A to D and on that line, *away from* the sun, we lay out the corrected Sumner line, B to C, at right angles to the sun's bearing and running through the point of the corrected position at D.

From this result, however, the "fix" or exact latitude and longitude is not obtained.

The navigator has simply corrected his D. R. Sumner line (Fig. 11, E to F) and, by the St. Hilaire method, has found the true Sumner line (B to C) and knows that his ship is somewhere on that line.

To find his exact position he must wait about two hours or until the sun has changed its azimuth about two points and then repeat the operation by St. Hilaire. This gives exactly the same problem as shown by Sumner method C, on page 19.

The following diagram demonstrates how a fix is obtained by a second sight, as above. In this, as in the succeeding diagrams, the heavy black lines indicate the *corrected* Sumner lines.

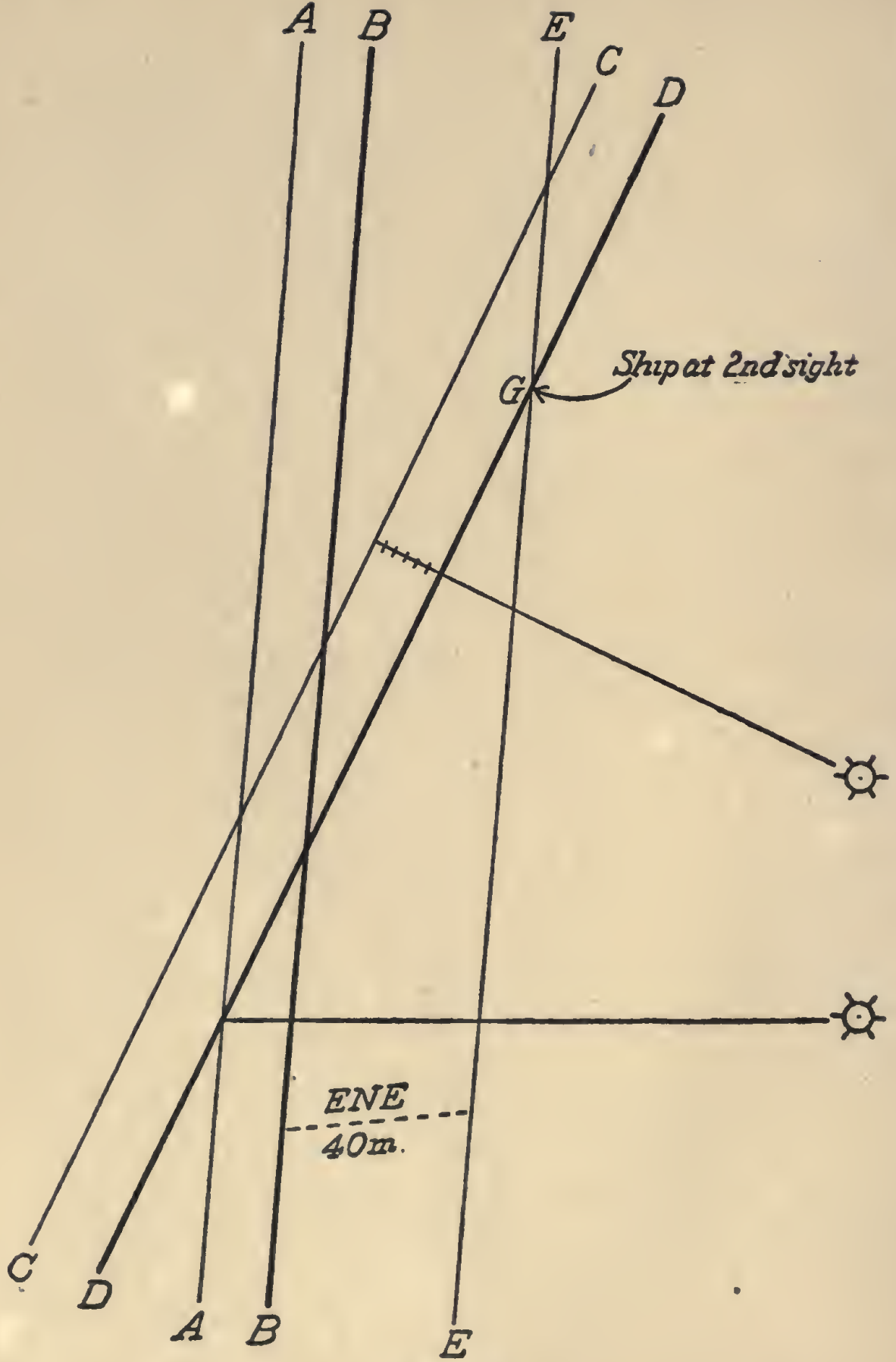


Fig. 12.

Fig. 12

A A═1st D. R. Sumner line
B B═1st D. R. Sumner line, corrected by St. Hilaire
C C═2nd D. R. Sumner line
D D═2nd D. R. Sumner line, corrected by St. Hilaire
E E═first line extended 40 miles parallel to B B

The student should study this diagram carefully in comparison with the Sumner diagram on page 20. He will find that the Sumner lines A A and C C are the same; and that, by the St. Hilaire method, A A has been advanced to B B and in the same way C C has been advanced to D D. Therefore the new or corrected Sumner lines are B B and D D; and their intersection at G is the position at time of the second sight. The line E E is simply B B advanced to the end of the intervening run, E. N. E. 40 miles, as shown. The respective bearings or azimuths of the sun remain unchanged.

Now it must be borne in mind that this form of the problem involves the working out of two sights or positions; the first as early as possible and the second about two hours later, or as soon as the sun has changed its azimuth about two points. Thus, if the first sight is taken at about half past seven or eight o'clock the ship's position or fix may be determined at half past nine or ten. Therefore this method is only desirable when the navigator, by reason of the proximity of land or for any other rea-

son, wants to know his exact position as early as possible, and prefers not to wait until noon.

If, on the other hand, he is well off shore and has plenty of sea room, he does not need to know his exact position before noon, in which case he adopts the Sumner Method B, as explained on page 12, corrected by St. Hilaire.

For example, take an early morning sight, dot the D. R. position on the chart, estimate the local apparent time and find the sun's true bearing from the azimuth tables. At right angles to this line of bearing draw the first Sumner line and by the St. Hilaire method find the corrected or *true* Sumner line which must be plotted on the chart also at right angles to the sun's bearing. Then wait until noon, find the latitude by the usual meridian observation and on the latitude thus found draw a line on the chart which must run East and West and, therefore, at right angles to the sun's bearing because at apparent noon the sun *must* bear North or South. Now advance the corrected Sumner line from the morning sight up to noon, by the usual course and distance by D. R., drawing it parallel to the other line. Then project this advanced

line on the chart until it crosses the line of latitude at noon and the intersection of these two lines on the chart gives the ship's position at noon, both latitude and longitude, as will be seen by the diagram, Fig. 13.

In this case the D. R. position, at say eight o'clock in the morning, is dotted on the chart at E. The sun's azimuth is found to be N. 130° E. and at right angles to that bearing the Sumner line is drawn at A B. Then by St. Hilaire we find the corrected or true Sumner line C D, through the point F. Waiting until noon we draw the line H K along the ascertained latitude. Now we find that from 8 A. M. to noon the ship has sailed E. N. E. 60 miles. Therefore the corrected Sumner line is advanced from F to the end of the run at M and through the point M we draw a line J L parallel to the Sumner line D C and where this last line intersects the line of latitude, at G, is the position of the ship at noon.

Supposing now that after taking the early morning sight the sky is clouded over or the ship runs into a fog and at noon the sun is obscured so that we cannot get the latitude by

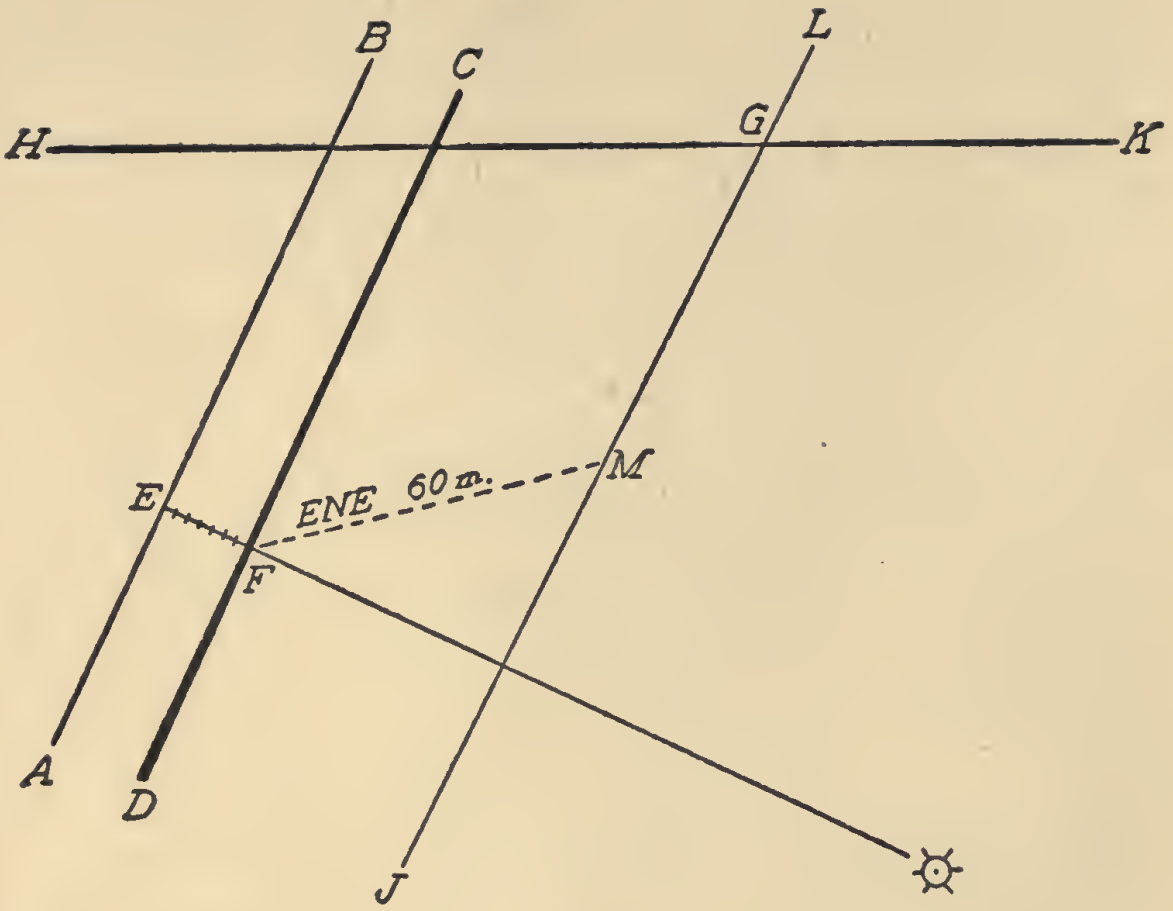


Fig. 13

H K=Lat. by meridn. obs. at noon
E=A. M. position by D. R.
F=A. M. position corrected by St. Hilaire
A B=Sumner line by D. R.
C D=Sumner line, corrected by St. Hilaire
L J= line parallel with D C, extended to end of course and distance
F M=run from morning sight to noon
G=ship's position at noon (showing latitude and longitude)

observation. Then, if the sun comes out again in the afternoon, we use the Sumner Method D, as described by Fig. 6 on page 23. (See Fig. 14.)

By the St. Hilaire method correct the Sumner line of the morning sight and draw it on the chart. Work out the afternoon sight in the same way, apply the St. Hilaire method and draw the corrected afternoon Sumner line on the chart. By dead reckoning ascertain the course and distance run between the morning and afternoon sights. From the morning corrected Sumner line project this run on the chart and at the terminus of this run draw the advanced Sumner line parallel to the first line. The intersection of this advanced Sumner line with the afternoon corrected Sumner line will give the position of the ship at the time of the afternoon sight.

The principle involved in this problem is of course the same as in the others; but its accuracy is lessened somewhat by the greater length of the run between sights which of course must be estimated by dead reckoning.

Now let us take the Sumner Method D and correct it by St. Hilaire. To do this intelligent-

ly we must study carefully Fig. 6 on page 23 and compare it with the diagram in Fig. 14.

In this case, in correcting by St. Hilaire, we find that the first Sumner line must be moved 4′ *away* from the sun (to P) and the second Sumner line must be moved 3′ also *away* from the sun (to O).

Now it will be obvious that the corrected morning Sumner line, advanced to the terminus of the run, must intersect the afternoon corrected Sumner line and that the point of that intersection (at G) must give the position of the ship at the time of the second sight.

During daylight we usually have only one body to observe, viz., the sun. There are times, however, when the moon is also visible while the sun is out and this gives an opportunity to observe 2 bodies simultaneously and so to be able to calculate a fix at once, without the delay in waiting for a second observation of the sun.

For the same reason, if we have a good horizon at night, an observation of two stars at the same time is most desirable as it gives us our position at once, as will be hereafter demonstrated.

The best time for observing stars is during

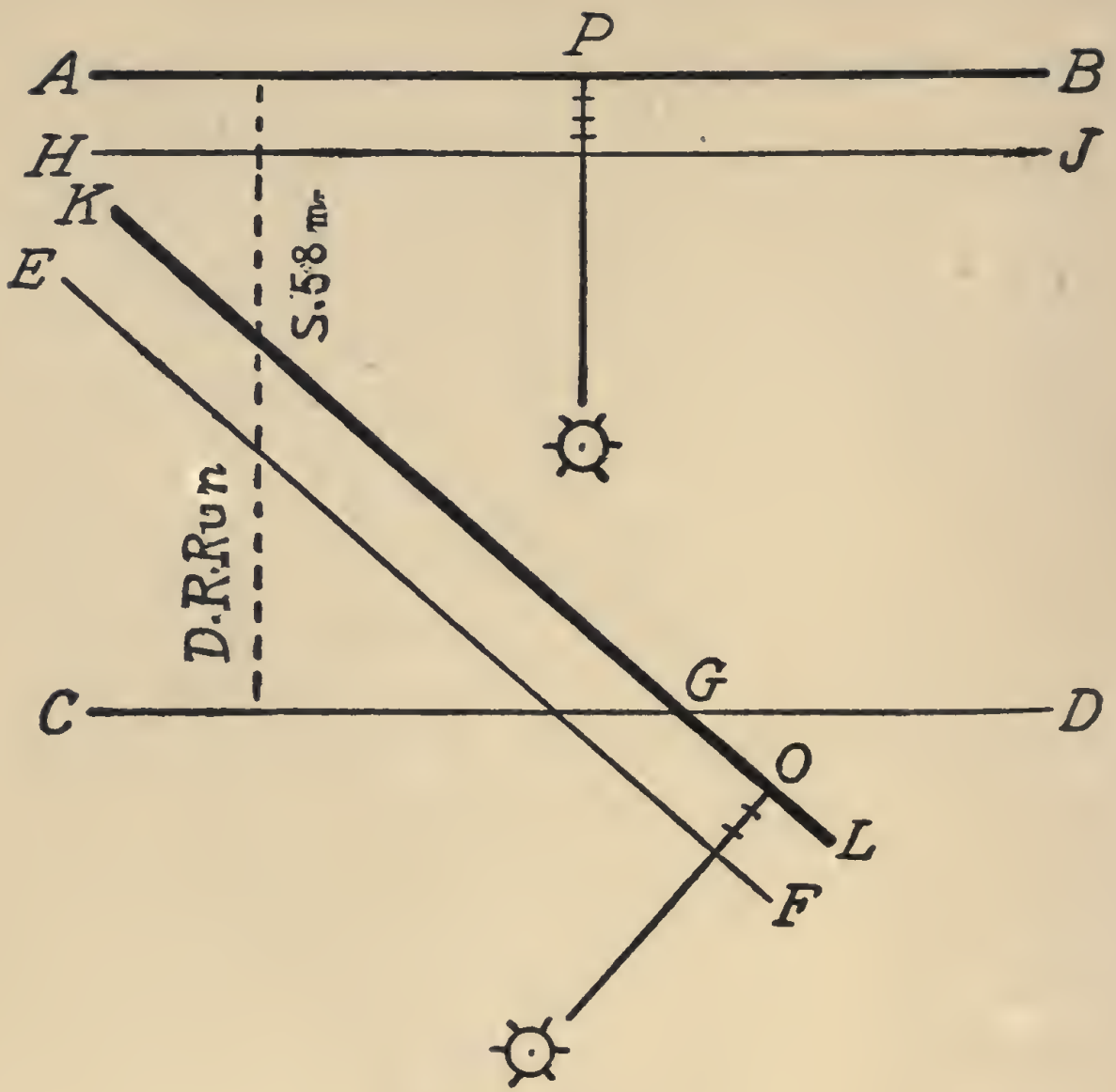


Fig. 14.

H J } E F } = Sumner lines by D. R.

A B } K L } = Sumner lines, corrected by St. Hilaire

C D = first Sumner line (corrected) advanced to terminus of run and parallel to first line

G = position of ship at time of second sight

the evening twilight or the morning dawn, while the horizon is clearly defined. For this reason the author, when at sea, has always chosen to stand the morning watch, from four to eight o'clock, because just before sunrise there is a short period when the horizon is distinctly visible before the stars disappear.

Now let us next consider an observation of the

Sun and Moon Simultaneously

Lieut. F. C. Cross, R. N. R., in his book entitled "The New Navigation," gives an interesting example of a simultaneous observation of the sun and moon. Under certain conditions the moon may often appear before the sun has gone down.

Example

Ship's position by D. R., Lat. 45° 24′ S., Long. 49° 16′ W. Sun's azimuth N. 10° W. Moon's azimuth S. 58° W. By the St. Hilaire method it was found that in the case of the sun the ship was 1′ *nearer* than by D. R.; and in the case of the Moon the same result was given, i. e., 1′

nearer than D. R. This is illustrated in the following diagram:

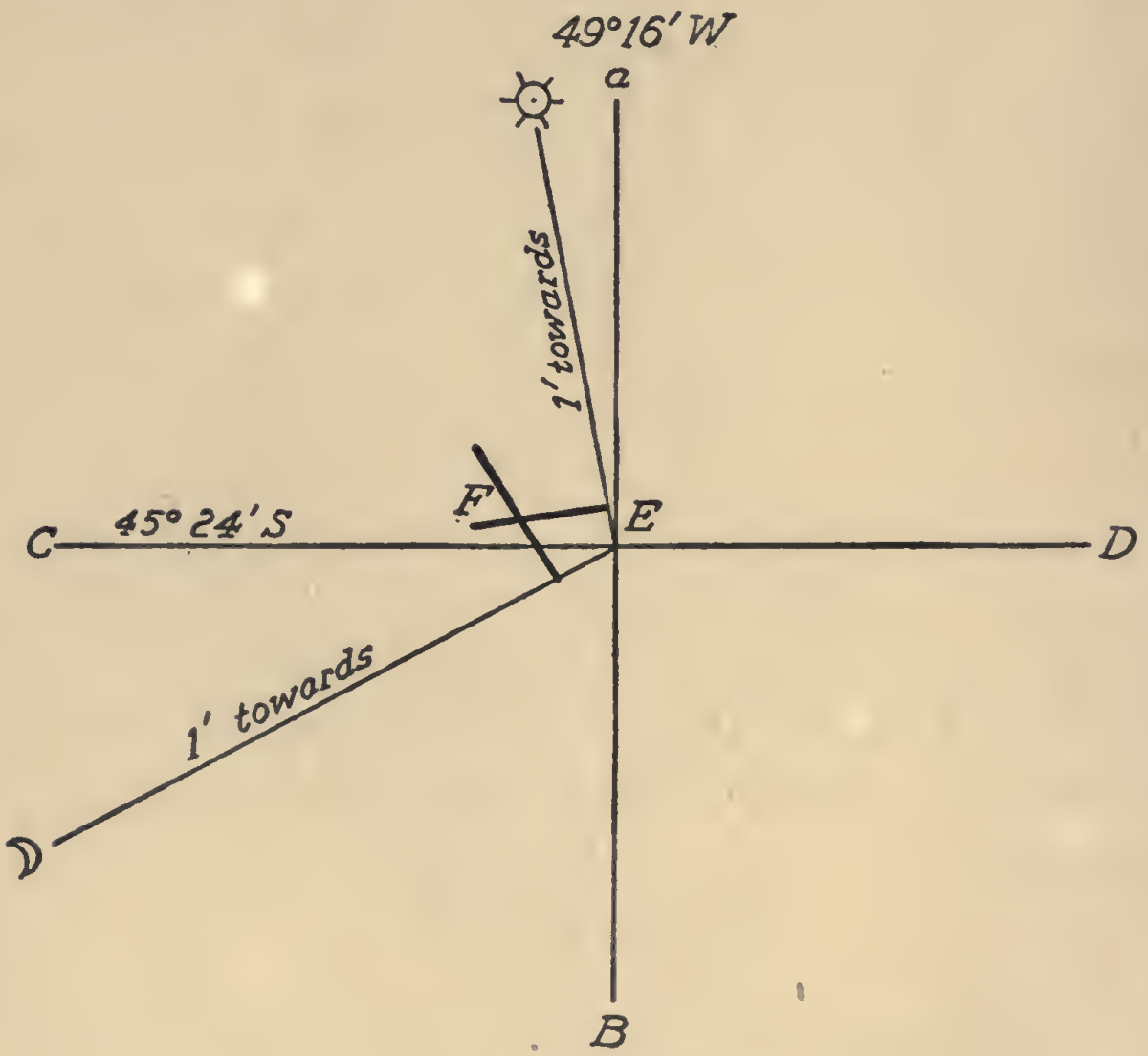


Fig. 15.

The perpendicular line A B is drawn on the meridian of the D. R. longitude, 49° 16′ W., and the horizontal line C D on the D. R. lat.,

45° 24′ S. and therefore the intersection of these lines gives the position of the ship by D. R., at E. The two Sumner lines are drawn *nearer* the respective bodies, as shown in the diagram, and the intersection of these two lines gives the exact ship's position at F.

In this case, as the observations of the two bodies are taken at the same instant, or one immediately after the other, there is of course no allowance to be made for the usual "run between sights" and therefore the possibility of error in the estimated run is eliminated.

Stars by St. Hilaire

In applying this method to the stars the only difference is in the method for ascertaining the Hour angle which is necessary, in order to get the first log haversine; and also to calculate the azimuth when the declination of the star exceeds 23° N. or 23° S. Within these limits the ordinary azimuth tables may be used. Following is the rule for computing the

Hour Angle of a Star

To the Greenwich Mean Time, as shown by the chronometer at time of sight, apply the rate (fast or slow) and to this corrected G. M. T. apply the longitude in time, adding it if the ship is East and subtracting it if the ship is West of Greenwich. Convert this local Mean Time into local sidereal time by adding to it the sun's right ascension at time of sight. This gives the local sidereal time which, as the student will remember, is the right ascension of the meridian (R. A. M.).

From this R. A. M. always *deduct* the star's right ascension and the result will be the star's hour angle (H. A.) West.

If the star's H. A. West exceeds 12 hours it should be deducted from 24 hours to get the H. A. East, as explained with the sun. Hence, an H. A. 21h. West should, strictly speaking, be named H. A. 3 hours (East). But for purposes of the Cosine-haversine formula it makes no difference in the result because in Bowditch Table 45 the log. haversine for 3 hours (reading from top of page) is

exactly the same as the log. for 21 hours reading from the bottom of the page. Bowditch calls it "H. A. or t"; and uses the small letter "t" for the hour angle. On page 157 will be found "LAT.=t, or H. A." In working the Cosine-haversine formula, when the astronomical time exceeds 12 hours he does not seem to think it necessary to deduct it from 24 hours but lets it stand. On the same page (157) will be found:

t 19h. 31m. 57s. log. havers. 9.48392

Now if we deduct this time from 24 hours we get the true East H. A. of 4h. 28m. 03s. of which we find exactly the same log. haversine (9.48392) by reading from the top of the page.

For example: at sea Jan. 3rd, 1918, in longitude 30° 15′ W., G. M. T. 7h. 16m. 11s. A. M., find the H. A. of Vega, whose declination is 38° N. and therefore out of the range of the ordinary azimuth tables. The A. M. civil time of 7h. 16m. 11s., Jan. 3rd would of course be Jan. 2nd, 19h. 16m. 11s. Astronomical mean time which we must always use with the stars.

From the foregoing data, applying the rule, we deduce the following:

G. M. T. (of Jan. 2)	19h. 16m. 11s.
Longitude, 30° 15′ W.	2h. 01m. 00s.
Mean time at ship	17h. 15m. 11s.
Sun's right ascension at noon of Jan. 2	18h. 45m. 15s.
Correction for 19h. 16m. Table III Naut. Alm. or 9 Bowditch	03m. 10s.
	36h. 03m. 36s.
Deduct	24h.
R. A. M., or local sidereal time	12h. 03m. 36s.
add for purpose of subtraction	24h.
	36h. 03m. 36s.
Deduct Vega's Right Ascension	18h. 34m. 09s.
"H. A.," or Vega's hour angle W.	17h. 29m. 27s

Of course the true *East* H. A. would be (as heretofore explained) 24h.—17h. 29m. 27s.= 6h. 30m. 33s., although the log. haversine would be the same.

NOTE. First deducting and then adding 24 hours is not necessary in actual practice but is given here merely to illustrate the rule.

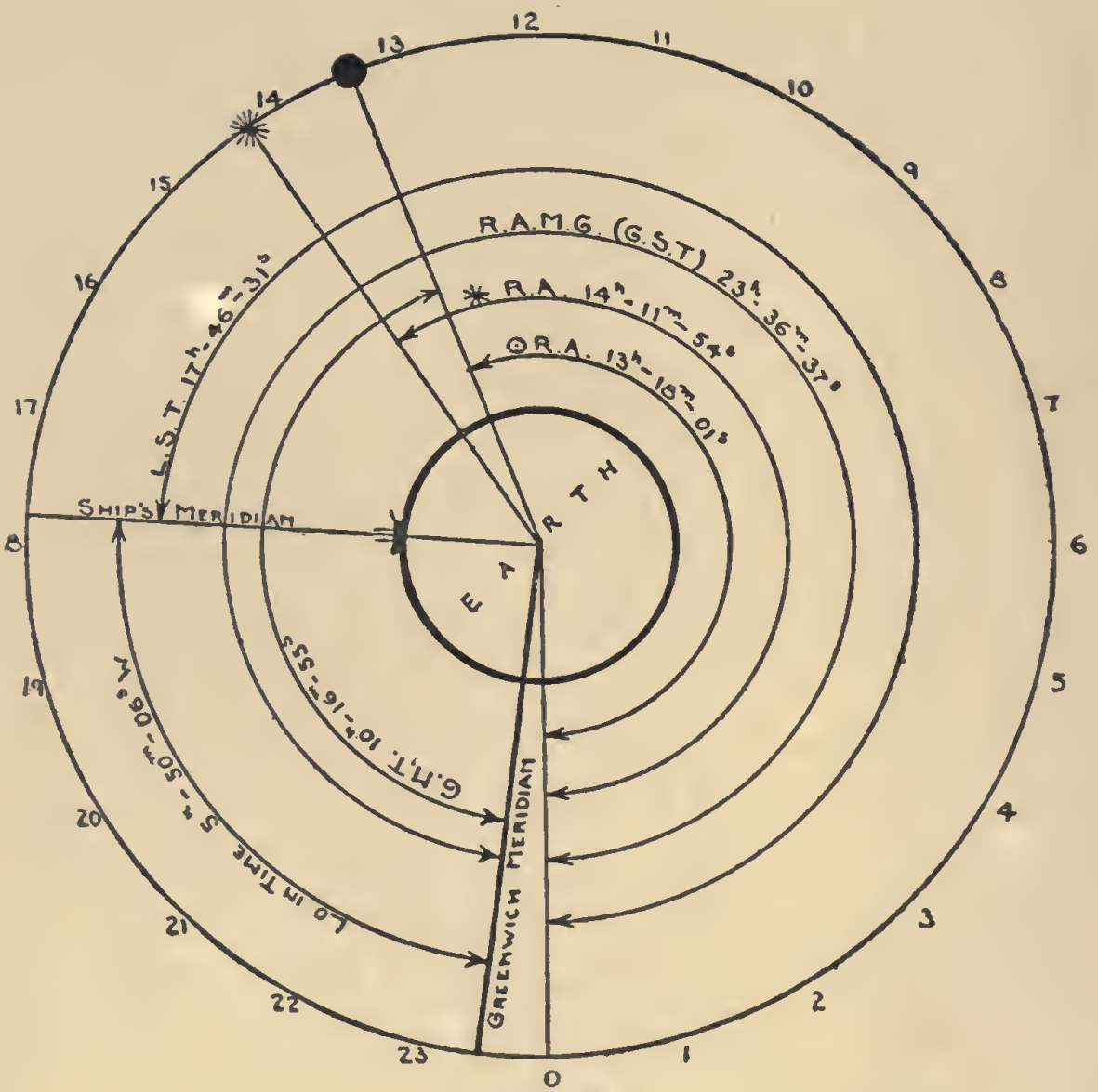
It is assumed that the student has already acquired a clear understanding of Sidereal

Time, the relations of Right Ascension, Hour Angle, etc.; but, if not, he is strongly recommended to study thoroughly this subject in that admirable and most lucid treatise on navigation by the author's friend and colleague, Lieut. Wm. J. Henderson.

The following diagram, designed and used by the instructors of the U. S. Naval Auxiliary Reserve at the great naval camp at Pelham, is by far the most lucid and complete that the author has found, and the student is urged to study it carefully and then to apply it to any examples involving sidereal time, right ascension, etc. (See Fig. 16.)

The figure O, at the bottom of the diagram, represents the First Point of Aries and the figures around the outer circle are the hours of the sidereal day which is only 23h. 56m. 04s. long. The difference between it and the mean solar day is 3m. 56s. and is known as the "Earth's Central Progress" (⊕ C. P.).

Now, having ascertained the star's H. A., and its declination being more than 23°, we follow the altitude-azimuth rule to find the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R.A.M.G. (G.S.T) 23h. 36m. 37s
R.A. 14h. 11m. 54s
O R.A. 13h. 18m. 01s
L.S.T. 17h. 46m. 31s
SHIP'S MERIDIAN
EARTH
G.M.T. 10h. 16m. 55s
LO IN TIME 5h. 50m. 06s W
GREENWICH MERIDIAN

Fig. 16.

Star's Azimuth

Find the true central altitude (T C A), the Lat. by D. R. and the star's Polar Distance; add these three quantities together and divide the sum by 2. From this half sum deduct the Polar Distance; or, if the P. D. is greater than the half sum, deduct the lesser from the greater, leaving what is called "Remainder" (Rem.). Then, from Table 44 Bowditch add the logs secant of the true central altitude, secant of the latitude, cosine of the half sum and cosine of the remainder. The sum of these logs will be a log. haversine of an arc (Table 45 Bowditch) which deduct from 180° and the remainder will be the azimuth.

Note. In N. latitude, A. M. azimuth bearings are reckoned N. so many degrees E.; and P. M. azimuths N., so many degrees W. In S. latitude A. M. azimuth bearings are reckoned S., so many degrees E., and P. M. azimuths, S., so many degrees W.

Example

Jan. 3rd, 1918, Lat. by D. R. 42° 50′ N., Long. by D. R. 30° 15′ W. Observed altitude of Vega, E. of meridian 22° 04′. Height of eye, 30 ft. T. C. A. 21° 56′, Chron. 7h. 16m. 11s. A. M. civil time of Jan. 3rd, or 19h. 15m. 11s. Astronomical time of Jan. 2nd (G. M. T.). Declination 38° 42′ N. Find the star's azimuth.

T. C. A.	21° 56′	sec.	.03263
Lat.	42° 50′	sec.	.13470
P. Dist.	51° 18′		
	2)116° 04′		
Half sum	58° 02′	Cosin	9.72381
P. D.	51° 18′		
Rem.	6° 44′	Cosin	9.99699
	123° 05′	Havers.	19.88813
	180°		
Azimuth	56° 55′		

As the ship is in N. Lat. and the star is in the East we name the azimuth N. 57° E.

Now having the lat. and long. by D. R., the H. A. and the true azimuth, we take the declination from the almanac, correct it to time of

sight and are then prepared with the necessary data for computing the altitude by St. Hilaire, exactly the same as with the sun.

Although, as explained on page 57, the only difference in the application of St. Hilaire to the sun or to the star is in the method of ascertaining the hour angle and the azimuth, it may not be out of place to give here an actual example of computing the altitude of a star, from a D. R. or assumed position, taking the data from the foregoing examples:

G. M. T.	7h. 16m. 11s. A.M.			
Long. W. (—)	2h. 01m. 00s.			
L. M. T.	5h. 15m. 11s.			
Ast. L. M. T.	17h. 15m. 11s.			
⊙ R. A	18h. 45m. 15s.			
Corr. T III.	03m. 10s.			
R. A. M.	36h. 03m. 36s.			
*R. A. (—)	18h. 34m. 09s.			
*H. A.	17h. 29m. 27s.		Log. havers.	9.75316
Lat.	42° 50′ N.		Cosin	9.86530
Decln.	38° 42′ N.		Cosin	9.89233
		=	Havers	29.51079
		=	Nat. havers	.32418
Lat.,-decl. =	4° 08′	=	Nat. havers	.00130
Zen dist.	69° 34′		Nat. havers (Z.D.)	.32548
Subtract from	90°			
Comp. alt.	20° 26′			

Now having found the *computed* altitude from the D. R. position, and having taken an observation with a sextant the instant the ship was on the D. R. position and having applied the altitude correction and so obtained the *true* altitude, the difference between the computed and true will be applied to the D. R. position on the chart exactly the same as with the sun.

There is another difference between the sun and the stars. In the day time the sun is usually the only body that can be used for observations; while after dark there are many stars available. Hence, when a star is observed, instead of waiting two hours and taking a second observation of the same star in order to get a fix, a much better method is to observe two different stars at the same instant, as described for a simultaneous sight of the sun and moon on page 55. This is by far the most advantageous application of the St. Hilaire method because the ship's exact position is ascertained in the shortest possible space of time.

Without giving the actual figures, which have already been fully explained, the following dia-

gram will serve to demonstrate what is known as a

SIMULTANEOUS ALTITUDE OF TWO STARS

Position by D. R., Lat. 34° 47′ S., Long. 12° 21′ W.

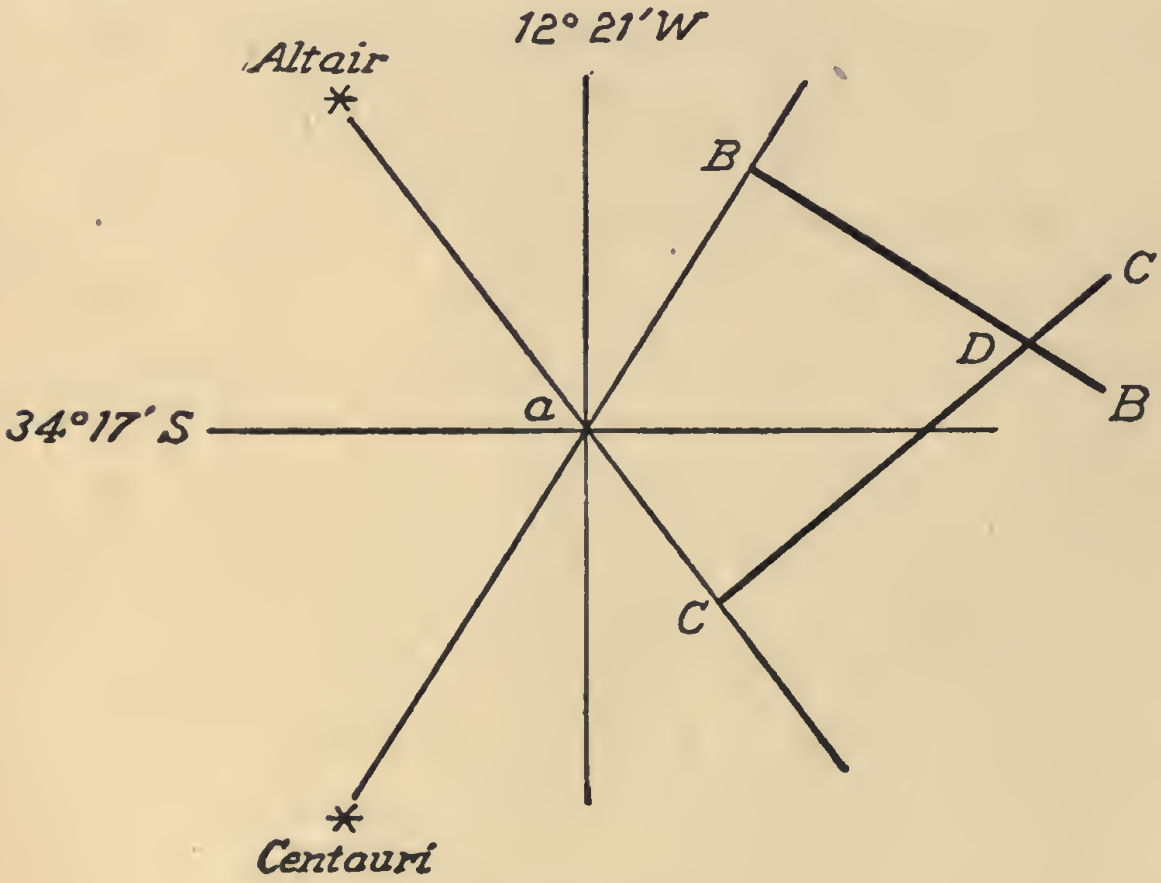

Fig. 17.

This useful diagram is found in "The New Navigation," by Lieut. F. C. Cross, R. N. R., hereinbefore referred to.

The perpendicular and horizontal lines indicate, respectively, the longitude and latitude on the chart; and the intersection of these two lines at A gives the D. R. position. Through this position a line of bearing is drawn towards each star, their respective azimuths having been previously computed and the stars located on the chart. At right angles to these two lines of bearing the respective corrected Sumner lines (lines of position) are drawn, *viz.*, for Altair C to C and for Centaur B to B. The intersection of these two lines of position at D gives the fix or exact position of the ship. Of course the D. R. Sumner lines would intersect the D. R. position at A; but by the St. Hilaire method, hereinbefore described, the Sumner line for Centaur has been moved 9½′ away from the D. R. position and that for Altair has been moved 5¼′ also *away* from the D. R. position.

One distinct advantage of this simultaneous observation of two stars is the elimination of the uncertainty of the D. R. calculation for the "run between sights," as explained with the sun and moon on page 55.

In some of the earlier diagrams herein given

the author has drawn the first "line of position" for the purpose of demonstration. This, however, is not necessary and is not generally done in actual practice. It is only necessary actually to draw the line of position, corrected by St. Hilaire, from or towards the sun, at right angles to its azimuth, and counting from the dead reckoning point. In some of the later diagrams this latter plan has been followed.

The question of working out St. Hilaire problems and finding the ship's position without drawing the diagrams on a chart is one that the author has carefully considered after conferring with Naval officers recently in actual practice at sea and also with others high in authority. The consensus of opinion seems to be that it is easier and much safer actually to draw the diagrams rather than to work out the problems by the use of the traverse tables which latter method is much more complicated and therefore more liable to error. One prominent Naval officer, with rank of Commander who has been captain of a U. S. destroyer in continuous service on the other side, told the author recently that, while he used the St. Hilaire method almost

exclusively, he would not allow his navigating officers to work out the problems without plotting them on a chart because the liability of error was too great.

Of course the single operation of correcting a single Sumner line of position without making a drawing on the chart is comparatively simple.

For example, a ship's D. R. position is in lat. 37° 51′ N. and long. 74° 40′ W. The sun's azimuth is N. 102° E. By St. Hilaire it is found that the corrected position of the Sumner line is 8 miles *away* from the sun. Hence, using the sun's bearing as a course we must reverse it by changing it from N. 102 E. to N. 78 W. Then we have the simple problem of taking our D. R. position as a departure and with the traverse tables find the position of the ship 8 miles N. 78° W. away from the D. R. position. This new position is not a "fix," but merely gives the point through which the *corrected* Sumner line must run, at right angles with the course of N. 78° W. Then again we have to calculate the direction of this corrected line of bearing at right angles with or 90° from the course which again gives rise to possible error. To work this problem

without using the chart we would have the following (using the D. R. position as our departure):

Lat. left	37° 51′ 00″ N.	Long. left	74° 40′ W.
8 miles at 78° = 1.7′ =	01′ 42″	Dep. 7.8′ = Long.	10′
Lat. in	37° 52′ 42″	Long. in	74° 50′ W.
add	37° 51′ 00″		
	2)75° 43′ 42″		
Middle lat.	37° 51′ 51″		

This gives the point through which the new Sumner line (corrected by St. Hilaire) should run, *viz.*, Lat. 37° 52′ 42″ N., Long. 74° 50′ W. Now to find the bearing of that line we have:

Sun's azimuth	N. 102° E.
" " reversed	N. 78° W.

The direction of the new line of bearing, at right angles of 90° from the above, would be N. 12° E. and S. 12° W. Now while the foregoing problem is comparatively simple, without the chart, there is nevertheless greater or less chance of error in reversing the course, and in using the traverse tables. How much simpler would be the following diagram on a chart. See

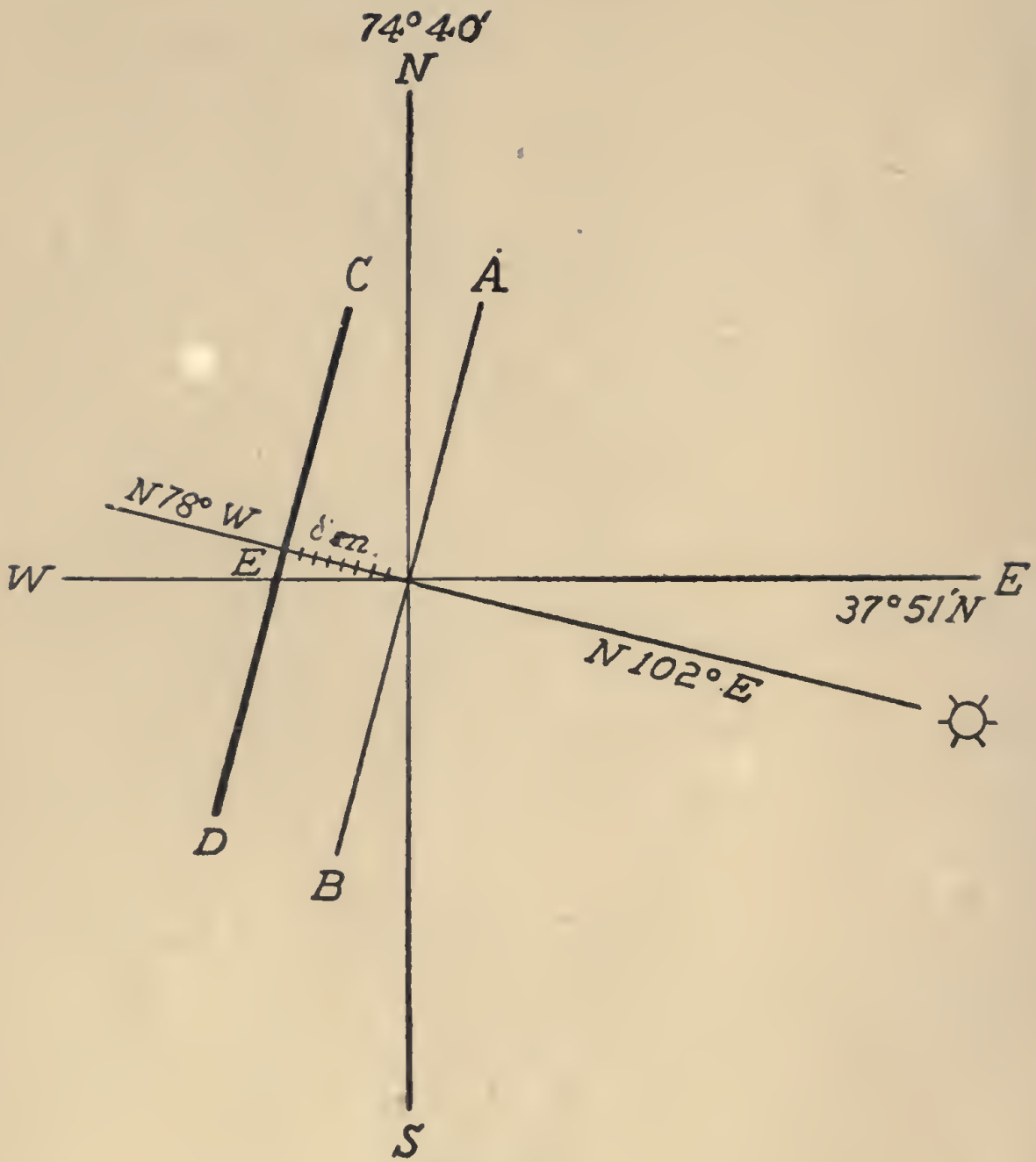

Fig. 18.

Fig. 18. A to B is the first Sumner line, drawn through the D. R. position at right angles to the azimuth of the sun. By St. Hilaire we find that the true Sumner line is 8 miles *away* from the sun. Hence we have the corrected line, C to D. Now if this diagram were drawn on a chart the dividers would give us instantly the corrected point at E; and the parallel rulers would give us the corrected line of position, C D,. drawn through that point.

The object of this book is to elucidate the *principles* of the Sumner-St. Hilaire methods, by the use of diagrams, so that the student or navigator may acquire a practical understanding of the subject. The use of these diagrams is strongly urged as not only the safest but the simplest method; but if the student desires to go further, let him first master the contents of this book which will be all sufficient for practical uses and then study Bowditch, Chapter XV, entitled "The Sumner Line." That chapter is a masterly scientific treatise on the subject from the standpoint of a profound mathematician; but for the student or even the ordinary navigator to acquire from it a practical understand-

ing of the Sumner-St. Hilaire methods without the ocular demonstration of the simple diagrams used in this book would be extremely difficult if not impossible. In Bowditch, Chapter XV, art. 372, it is stated:

"After finding the altitude-difference or intercept, the simplest procedure consists in laying it off on the chart from the assumed position and drawing the Sumner line through its extremity." In that same chapter the student may profitably read Article 371 and the first three paragraphs of Article 372 (pages 155 and 156). But when it comes to Article 376 entitled "Finding the Intersection of Sumner Lines" he will doubtless prefer to confine himself to the ocular demonstrations of the diagrams on the chart as given in this book; and for all practical purposes at sea, either in the Mercantile Marine or the Navy, he will need nothing more.

Compass Courses

The author is fully aware that he has laid himself open to criticism by using the old system of marking compasses from the meridian to East or West in 4 quadrants of 90 degrees each,

instead of the system recently adopted by the U. S. Navy having the degrees marked from 1° to 360°, reading from North, Eastward, around the compass. On the comparative merits of these two systems the author desires to be neutral; although he fully recognizes the advantages claimed for the Navy system. But the reader must bear in mind that this brief treatise is intended not so much for Naval officers but is specifically designed for the purpose of educating officers of the Merchant Marine in the improved navigation methods in use in the Navy. When the change in compass marking (1° to 360°) was inaugurated by the Navy department a careful canvass of the most prominent ship masters sailing out of New York was made and the opinions thus obtained were almost unanimously in favor of retaining the old system. For this reason it has been deemed preferable to use the old system in a treatise intended primarily for those by whom the new system is not yet used, and to whom it would be obviously confusing in the explanation and solutions of the various more or less complicated problems contained in this treatise. The student, however, is

strongly recommended to familiarize himself with the new system of compass marking if he has any idea of going into the Navy.

Among other reasons given by Merchant Marine navigators for not using the Sumner-St. Hilaire method is that it involves the use of special charts owing to the fact that the usual Mercator's charts are made to so small a scale that the necessary diagrams cannot be drawn on them with any degree of accuracy. On the usual tract chart one-eighth of one inch represents about 20 miles which would make it obviously impossible to draw the usual diagram.

Some of our modern coast charts are made on a larger scale but even on these the diagrams would be too small to be practical. The Hydrographic Office, under the auspices of the Navy Department, is now publishing a series of so-called "Position Plotting Sheets" the use of which is quite general. They are issued in a series of ten sheets covering from 60° N. to 60° S. latitude. They are about thirty by forty-two inches and are drawn on a scale of about 12 to 15 miles to the inch so that any of the diagrams can be easily and plainly drawn.

These plotting sheets must be selécted with reference to the latitude on which the ship is located, because, as the student will remember, the Mercator's chart is so constructed that the degrees of latitude grow slightly greater in length as we go North from the equator.

A new form of plotting sheet, specially designed for the Marcq St. Hilaire method, has recently been devised by Capt. Fritz E. Uttmark who succeeded the late Capt. Howard Patterson as head of Uttmark's Nautical Academy. This chart (patent applied for) has been approved by the Hydrographic Office and is a most ingenious device that may be used in any latitude from 60° North to 60° South. The sheet is only eleven by thirteen inches and is drawn on a scale of one inch to ten minutes of arc or about fifty per cent greater than the Hydrographic sheets. By means of a very clever, specially graduated scale, engraved on the side of the chart, the one sheet may be used in any latitude within the range stated. The author has used it in actual practice and has found it accurate, easy to use and in every way most satisfactory.

CHAPTER IV

A WARNING

In using any of these plotting charts too great emphasis cannot be laid on the necessity for caution when approaching land. The coast line which appears on the ordinary chart is a warning to the navigator to keep off; but on the plotting chart no coast line appears. Hence the imperative necessity of exercising the utmost caution. The only way to insure safety is to adopt an unalterable rule and then compel every navigating officer to follow it. Whenever the ship's position is found on the plotting sheet transfer it at once to the running chart whereby the navigator will at all times have an ocular demonstration of the ship's proximity to land.

Frequent soundings are, of course, absolutely indispensable. So often a ship has been run ashore because the captain's *belief* as to his position was wrong. Belief is not knowledge.

Knowledge can come only from demonstrated facts; as for example, the lead and line. When approaching land *never* rely wholly on the Sir William Thompson or any other sounding machine. The tubes have quite frequently been known to become deranged for some reason or another thereby seriously endangering the ship. A friend of the author's, crossing on one of the big Cunarders, was approaching the Irish coast in a fog. Suddenly the great ship was stopped and the deep-sea hand lead was cast. The Captain was asked whether he had a sounding machine on board. He replied, "Yes, I have one, but when I am nearing land in a fog I take no chances, I want to be *certain* of my position."

The cautions used by the Cunard officers may sometimes seem to the layman to be excessive; but who can remember a single instance of a Cunarder going ashore in a fog?

The author has been on a Cunarder when men were stationed ready to cast the lead as soon as a fog was encountered although the land was supposed to be at least 1,000 miles away!

When the *St. Paul* ran up high and dry on the Jersey beach the Cunarder *Campania* anchored

astern of her in 18 fathoms of water. The author crossed on the *Campania* with Captain Walker on the next East bound trip. Captain Walker, in relating the incident said: "I knew the *St. Paul* was just ahead of me, but I had been running on my dead reckoning three days and I did not *know* where I was; so when I found 18 fathoms, that was good enough for me and I let go my mud hook." On that occasion it is obvious that on the *Campania* they were sounding. Of course we don't *know* what was being done on the *St. Paul,* but the natural question is, when she struck in four or five fathoms, how long before that time had the lead been cast? An examination of the soundings given on a chart off the Jersey coast will warrant the assertion that it is a very easy and *safe* coast to approach, if the lead is kept going.

How often have these overcautious navigators been ridiculed and called "foolish"?

But the author's experience is that the so-called "foolish" navigator of this type rarely if ever meets with an accident.

Why did the *Princess Irene* run ashore in a fog on the Long Island coast a few years ago?

Perhaps the compass was to blame. But even the compass should *never* be trusted, particularly when running parallel to and near a coast line where the soundings are given so plainly that any novice would know enough to keep off. Suppose it were true that the ship ran ashore because the compass was deranged. That might be a reason but not an excuse. The author's contention is that if the lead had been properly used the ship would never have found herself in that locality.

For upwards of half a century it had been the proud boast of the Cunard Line that they had never lost a passenger until the *Lusitania* murders. Has that wonderful record been merely accidental or has it been attributable to good luck? NEITHER! It has been due to the utmost care and precaution, inaugurated by a wise and competent management, backed up by the most rigidly enforced discipline. This is a broad assertion but one or two incidents in the author's own personal experience will serve to justify it. Bound East on one of the big Cunarders, in mid-ocean, on a wonderfully beautiful day in May, with a perfectly smooth sea and an atmosphere

as clear as an October day in the mountains, the author was on the bridge just after taking the noon observation. Smoke was discovered on the Eastern horizon, dead ahead. Soon after appeared the masts, then the funnel and finally the hull of a small steamer. When we had approached to within about five or six miles, the officer of the watch gave the order, "Port"; and then, "South, 40° East" (about S. E. ½ S.), and the big ship, with the United States mails and a full quota of passengers, and running at a 22½ knot gait to beat a record, with plenty of sea room on a clear day, swung her head away around to starboard to avoid a miserable little Norwegian tramp of two thousand tons who held his own course flying the signals "Report me to my owners." After she was past our beam the order was given, "On course." When asked the reason for such a manœuver the officer of the watch replied, "Why, we don't know that chap, he may be asleep; or he might misunderstand signals. My orders are, to keep off and so avoid any possible chance of collision." Another foolish captain, say you? Well, that captain, one of the finest types that ever sailed the seas, is

long since dead, with a glorious record of never having had an accident!

Bound West, on the *Campania*, at a time when she and her big sister *Lucania* were striving for the record, when nearing midocean we passed a rival liner also bound East. Between these two ships there had been a great rivalry for speed. Just after passing the other liner huge icebergs were plainly visible to the East and North. Shortly thereafter we ran into a dense fog. Immediately the *Campania* was slowed down to her minimum speed, all watertight compartment doors were closed, additional lookouts were placed on forecastle head, crow's nest and bridge, and every precaution known to nautical science was adopted.

Soon we heard our rival's fog siren astern of us, coming nearer and nearer. A little later she appeared through the dense fog, headed directly for our taffrail. She sheered to port and passed closely alongside of us running at full speed. Captain Walker quietly remarked, "Well, he has a reputation to make for speed; but my instructions are for safety always. He may land his passengers Friday night; but I will keep

them till Saturday morning, give them a good breakfast and land them safely without having incurred the risk of an accident." Was Captain Walker characterized as "Foolish"? Not just then; the only comment heard among the passengers was: "Aren't you glad?" or, "Thank God we're on a Cunarder."

In departing from the main purpose of this book by the recital of the foregoing incidents, the author has been actuated by a desire to impress upon the mind of the young navigator the paramount importance of the common adage: "*Safety First!*"

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